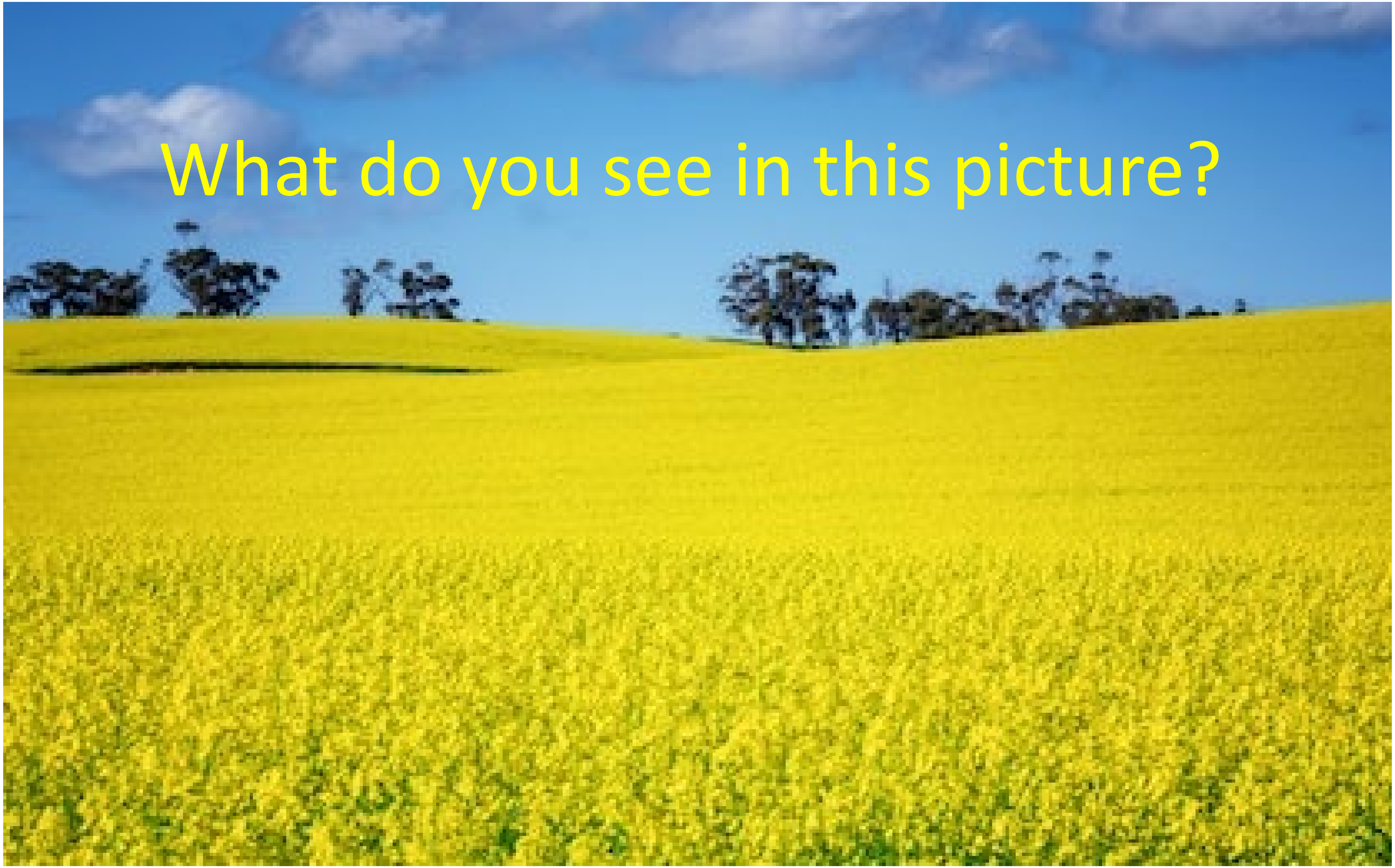
Considerations for Insect and Virus Management in Crops

Sean Michael Prager

UNIVERSITY OF SASKATCHEWAN
College of Agriculture and Bioresources
DEPARTMENT OF PLANT SCIENCES
AGBIO.USASK.CA

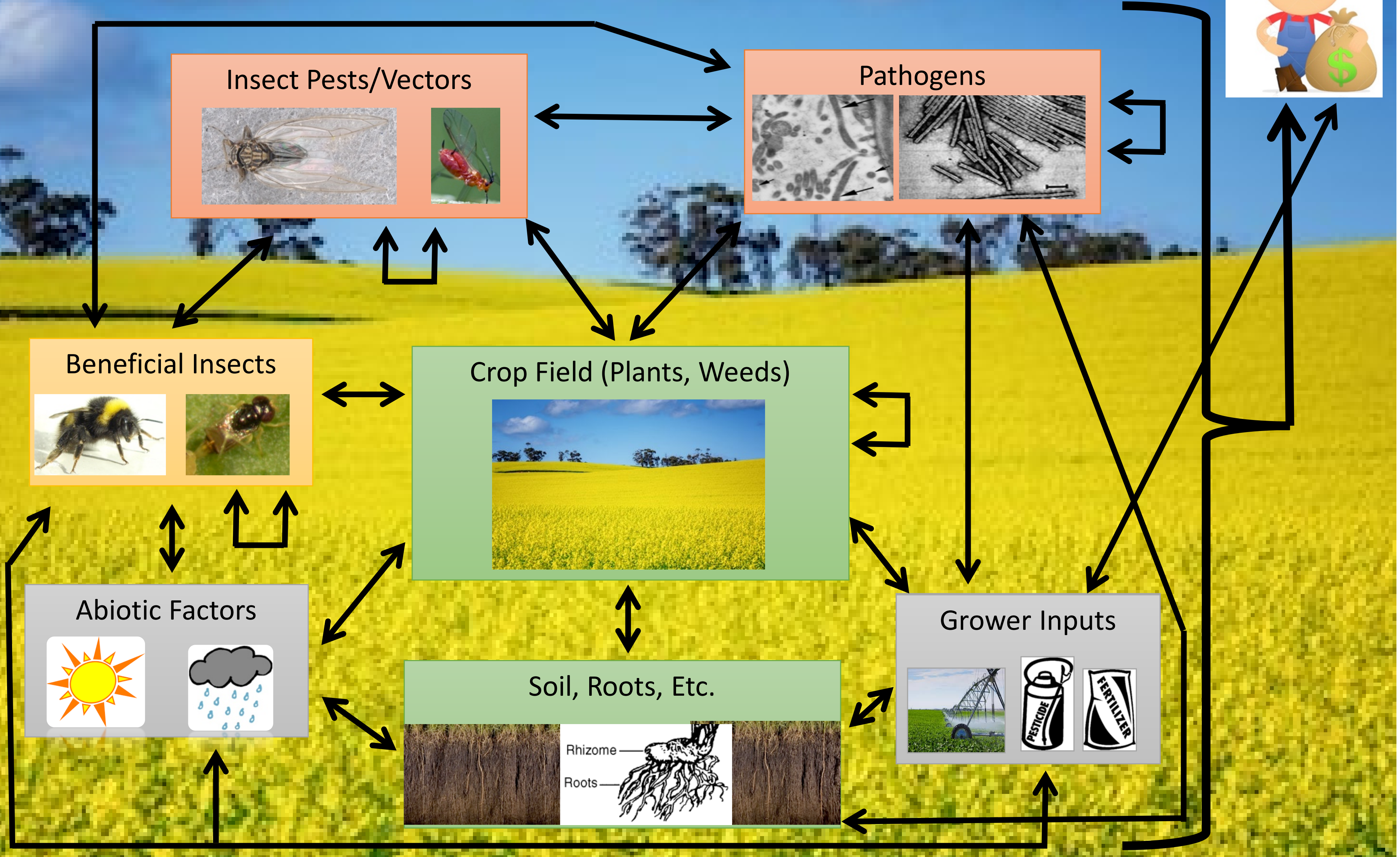

What do you see in this picture?

Many of you see this

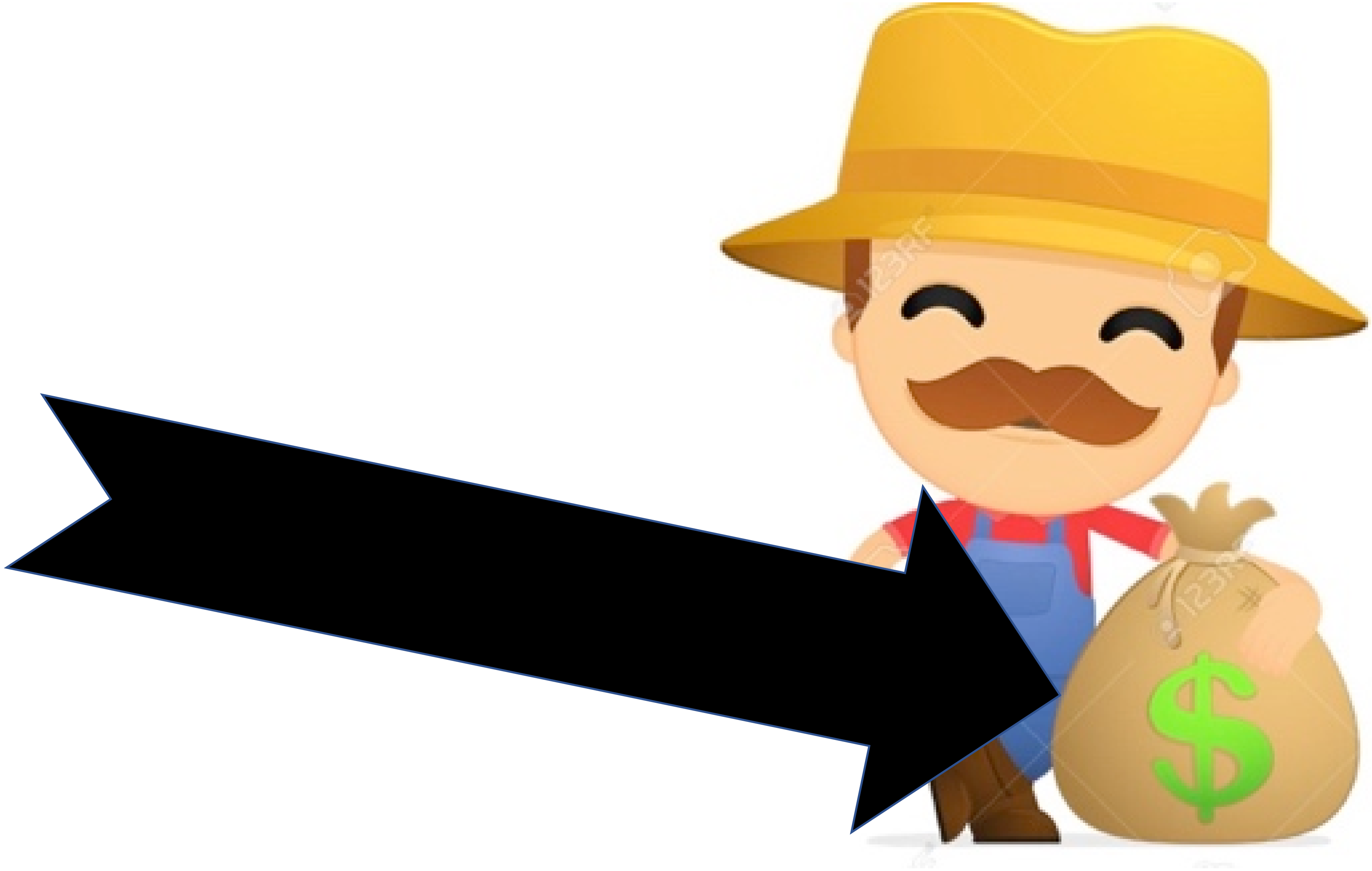
In a bad year, you may see this

We see this

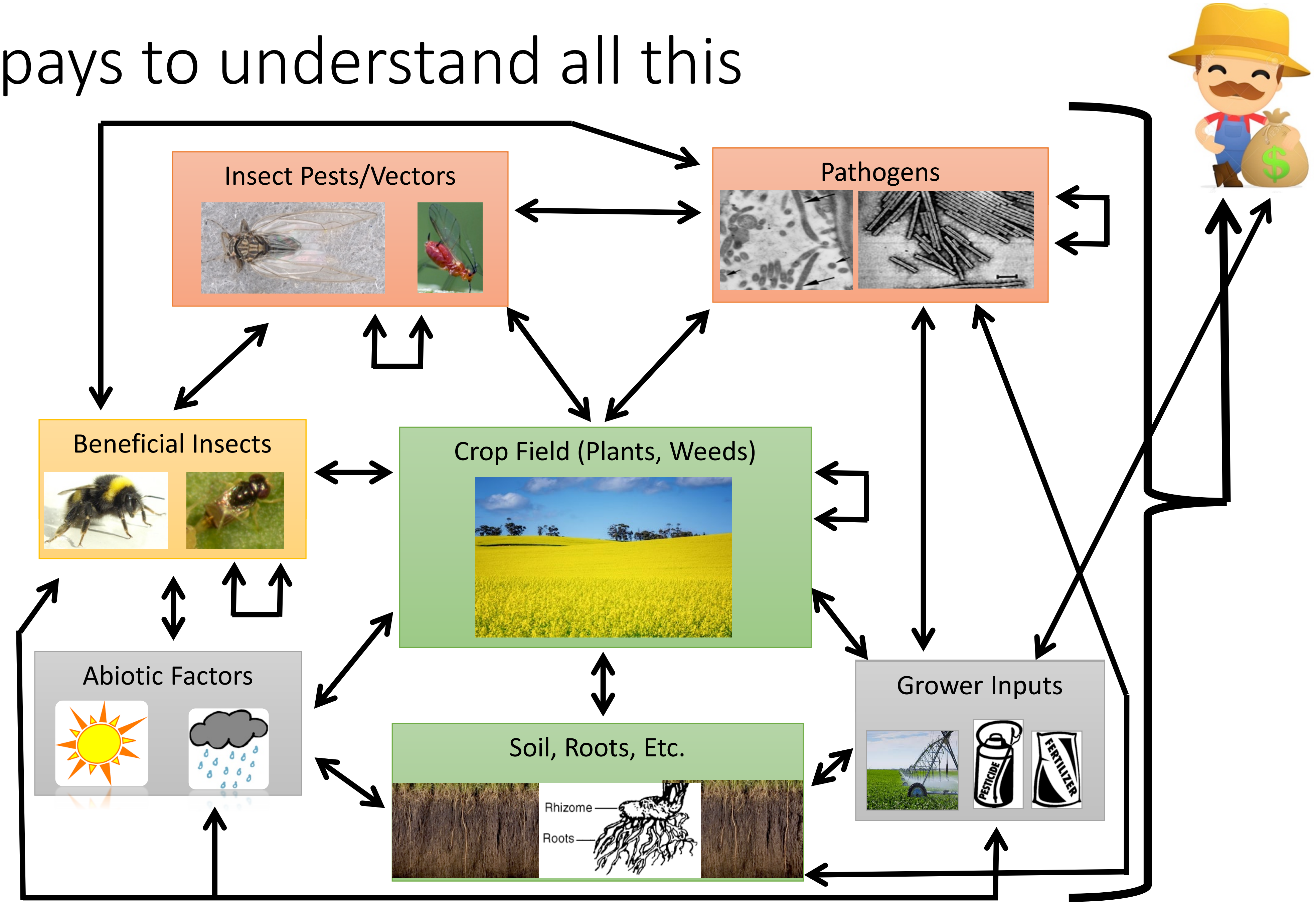
Many interacting factors



That all influence this

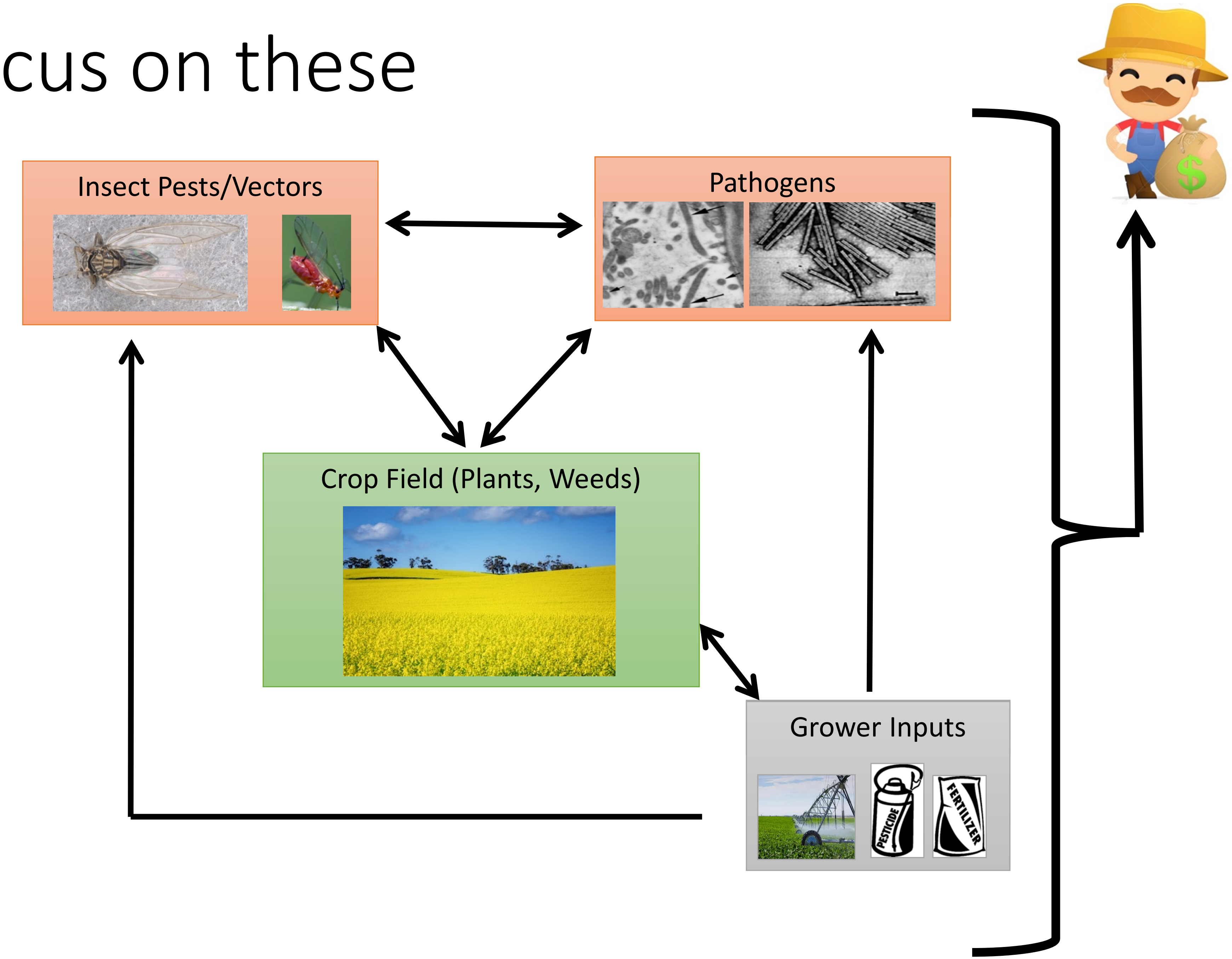


So, it pays to understand all this

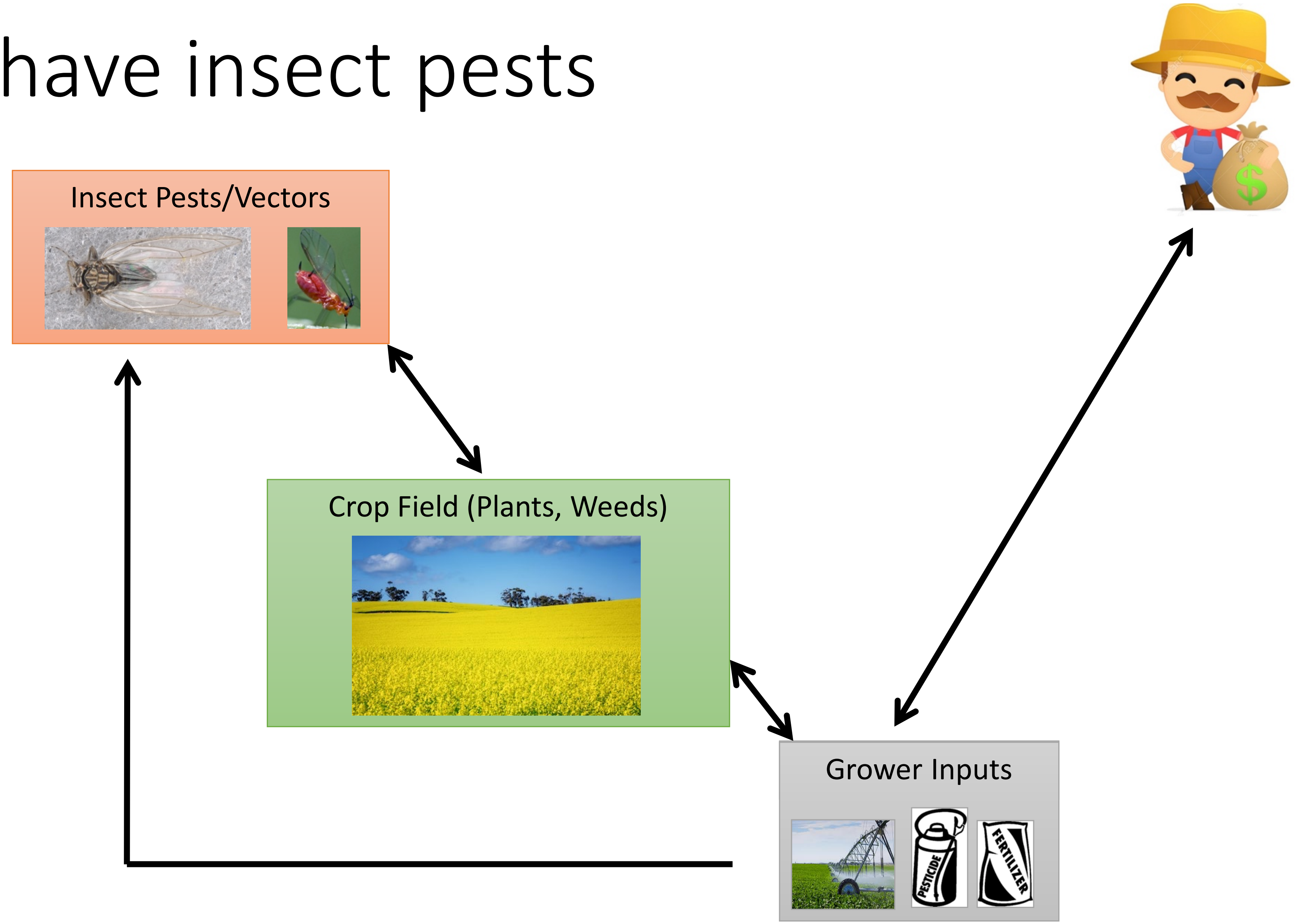


In the spirit of our conference theme-biotic stress

We will focus on these



When we have insect pests



Our first response is often, or usually, to apply an insecticide

But there are many things we should consider when we decide to take management action:

1. Distribution of pest
2. Which insecticide to use?
3. Is using the insecticide cost effective?
4. Is this a common pest or an unusual/uncommon one?
5. Beneficial insects and/or pollinators
6. Neighbors
7. Other susceptible crops
8. Perhaps weeds?
9. Is the pest a vector?
10. Is your crop resistant/tolerant?

An example from horticulture

Potato/Tomato Psyllid (*Bactericera cockerelli*)

- Hemiptera: Sternorrhyncha: Psyllioidea: Triozidae
- Phloem feeding with specialized mouth parts
- Can access phloem in < 2 hours
- Females can lay 1000s of eggs in lifetime
- Egg to adult in about a month

Psyllids (and Lso) are an Important Pest

- Feeding results in “Psyllid Yellows”
- Honeydew promotes “sooty molds”
- Nutrient deficiencies
- Primary North American vector of *Candidatus* Liberibacter (Lso)
- Pest of tomato, eggplant, pepper and especially potato
- Lso has caused 10s of millions of dollars in losses

In California, this covers many important crops

California Crops

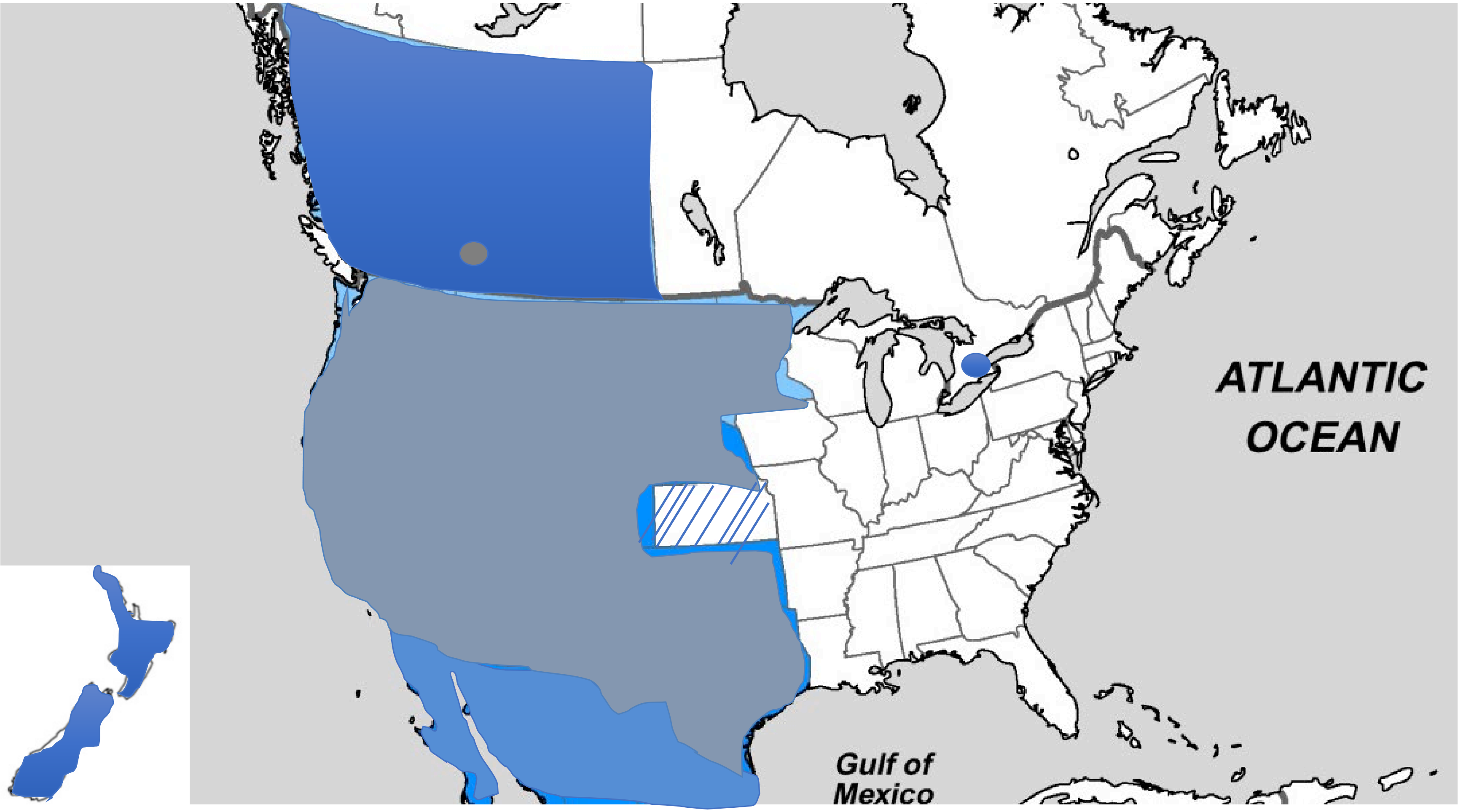
More than half of the country's vegetables, fruits, and nuts are grown in California.

Almonds	99%	Celery	95%
Artichokes	99%	Apricots	94%
Dates	99%	Wine Grapes	92%
Figs	99%	Strawberries	90%
Kiwifruit	99%	Cauliflower	90%
Olives	99%	Avocados	87%
Clingstone Peach	99%	Lemons	89%
Pistachios	99%	Carrots	86%
Pomegrantes	99%	Lettuce	78%
Walnuts	99%	Spinach	62%
Garlic	97%	Chili Peppers	57%
Plums	97%	$\boxed{\text{Bell Peppers 49\%}}$	
Broccoli	96%	Rice	26%
Nectarines	96%	Sweet Potatoes	23%
$\boxed{\text{Tomatoes, Canned 96\%}}$		Milk and Cream	21%

Source: California Department of Food and Agriculture

Plus 20,000 acres of potato

But they have a large geographic range



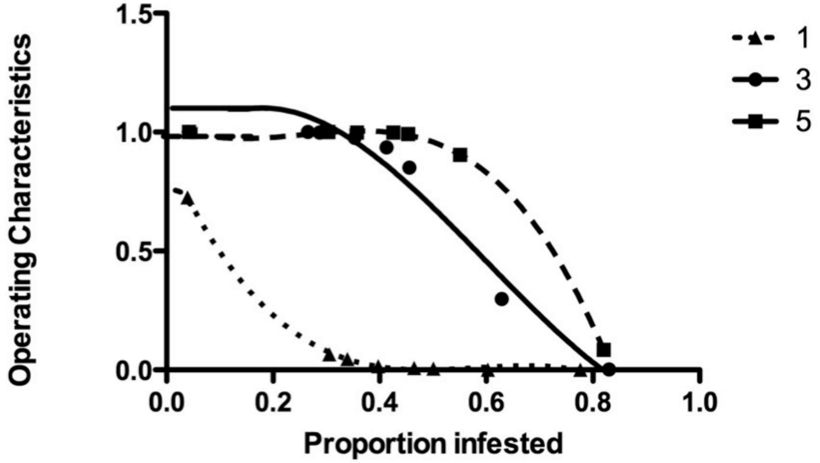
New Zealand

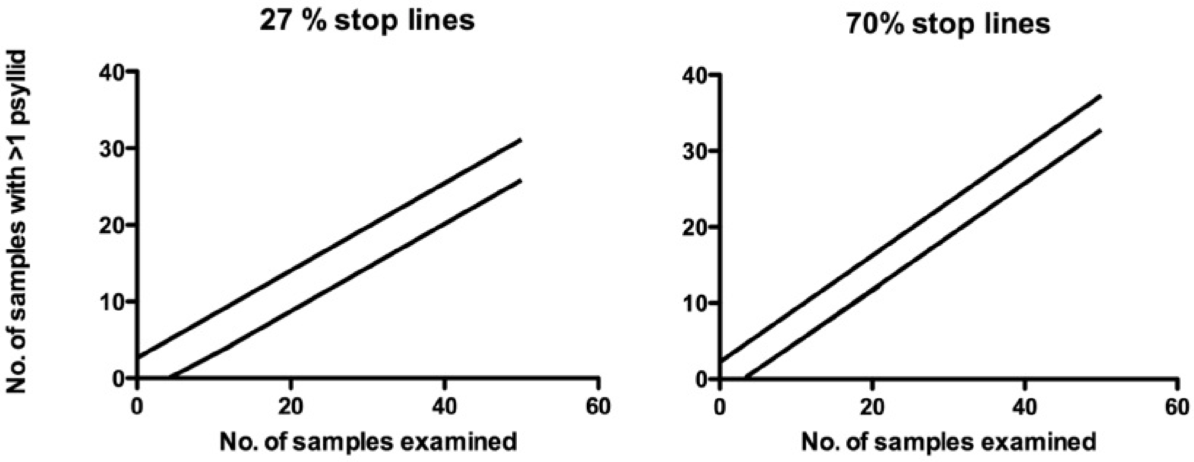
Also most of
Central America!

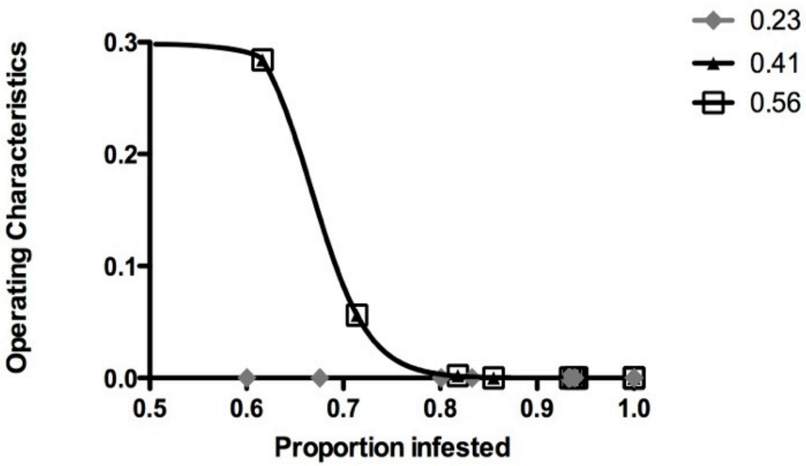
But distribution in crops differs

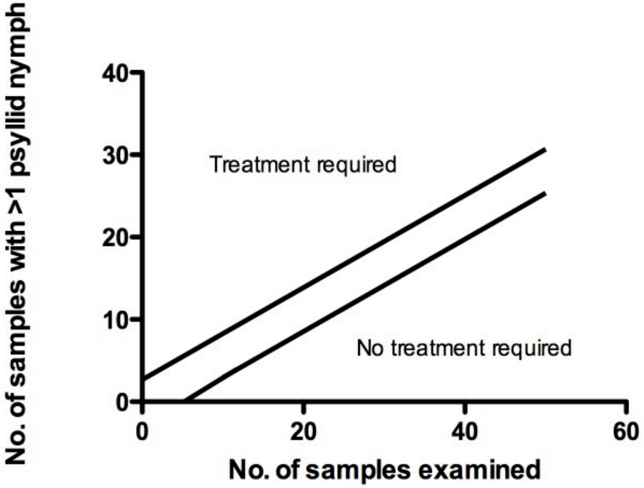
	Potato 	Tomato 	Pepper 
Mean Density	0.08-7.20 psyllids	0.4-743.1	20.0-50.5
Spatial Distribution	Aggregated	Eggs & nymphs aggregate Adults uniform	Clumped/uniform
Edge Effect	Yes	Yes	No
Leaf side preference	Abaxial	Abaxial (nymphs & adults) Eggs no preference	No preference
Location within plant	Top	Top (changes over time)	Top and middle

And this influences sampling plans









Prager et al. 2013, 2014

Which brings us to:

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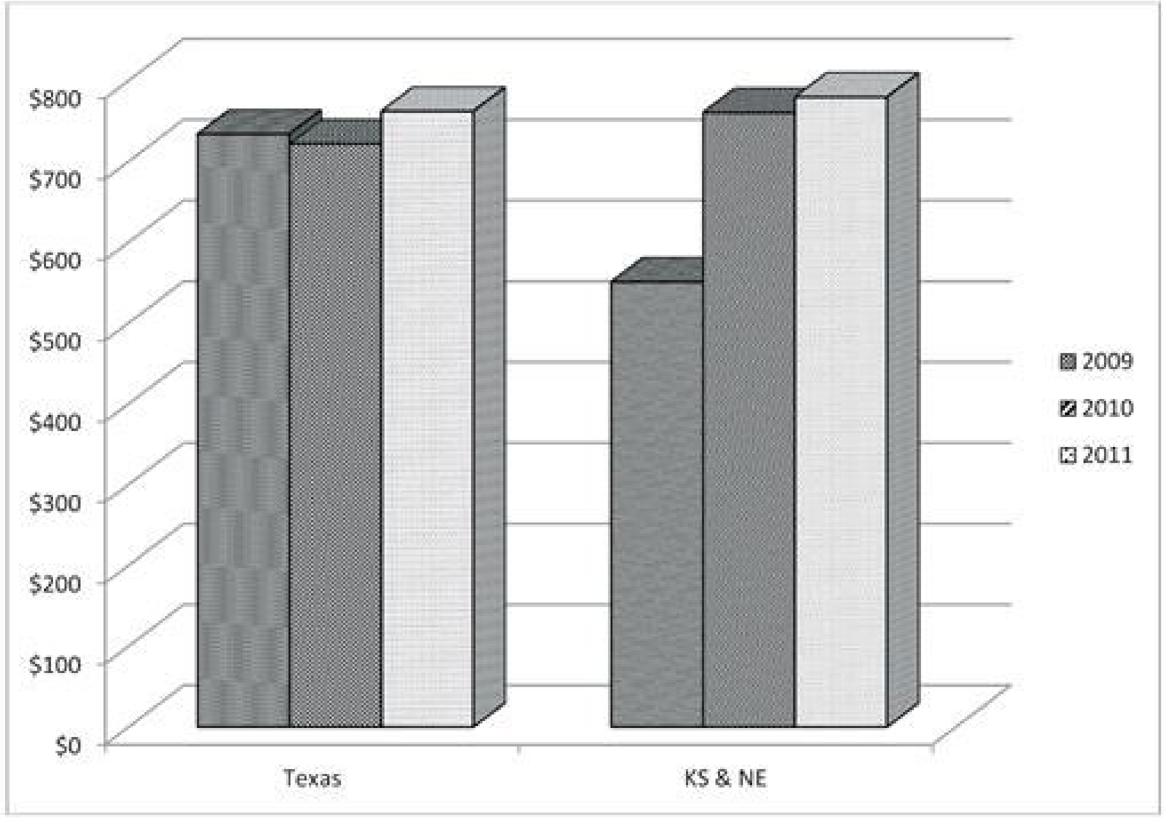
Because insecticides to control is expensive

Average insecticide cost per hectare for zebra chip and psyllid control



Guenthner et al 2012

Pathogens influence thresholds and costs

Table 3 Comparison of estimated baseline cost and use estimates for control of potato psyllids in the Columbia Basin with a no ZC scenario

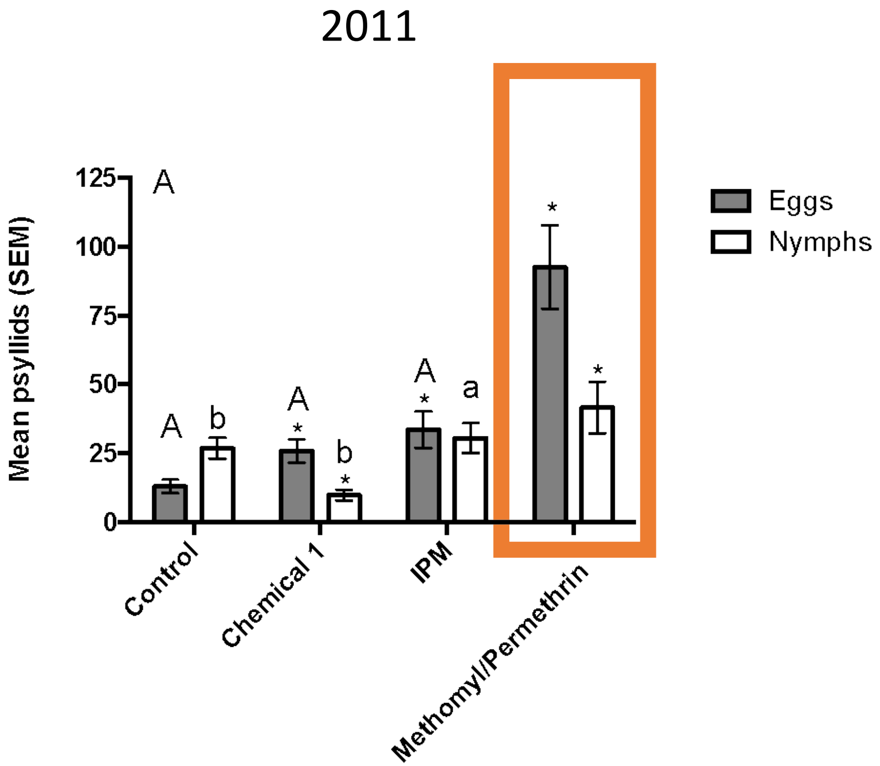
Baseline estimates				No ZC scenario		
	Liters	Product cost $ US dollars	Product and application cost $ US dollars	Liters r educed	Product cost saved$ US dollars	Product and application cost saved$ US dollars
Abamectin	10,826	$578,406	$744,806	7310	$390,424	$502,744
Esfenvalerate	22,232	$668,995	$1,820,995	2222	$66,900	$182,100
Flonicamid	5300	$1,774,080	$2,254,080	2252	$753,984	$957,984
Imidacloprid	13,911	$644,448	$1,092,448	522	$24,167	$40,967
Pymetrozine	2915	$596,288	$730,688	1094	$223,608	$274,008
Spiromesifen	6049	$496,964	$752,964	2495	$204,998	$310,598
Spirotetramat	7382	$1,762,176	$2,069,376	5277	$1,259,956	$1,479,604
Total	68,615	$6,521,358	$9,465,358	21,172	$2,924,036	$3,748,004

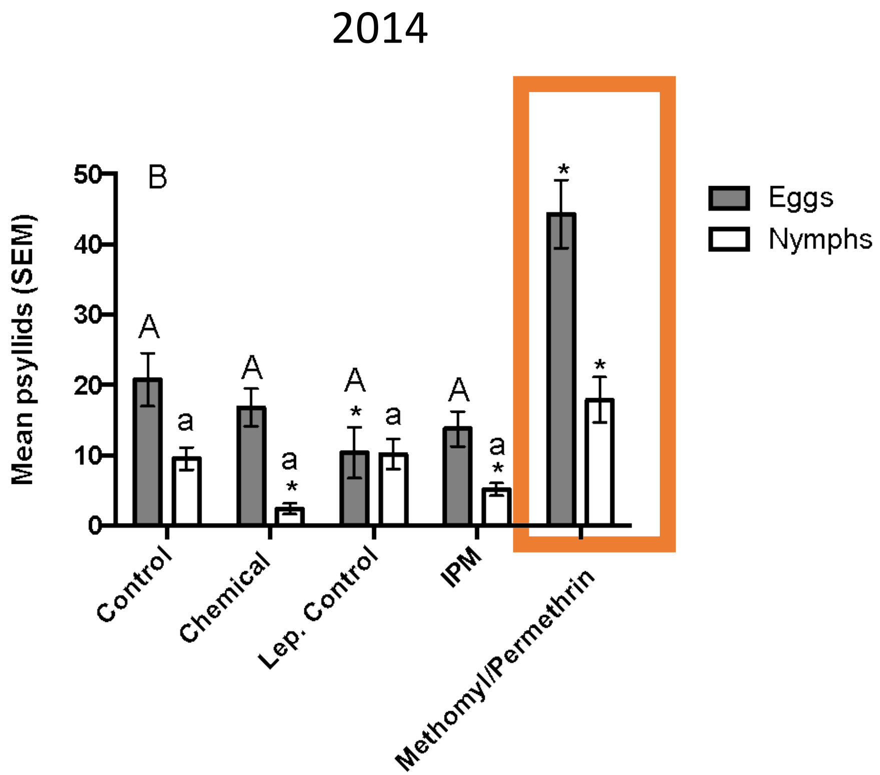
Greenaway and Rondon 2018

Pest Complexes?

- In 2014 Central Valley pepper growers reported extreme psyllid infestations
- Likely used “broad spectrum” insecticides to target pepper weevils

And Broad Spectrum = More Psyllids





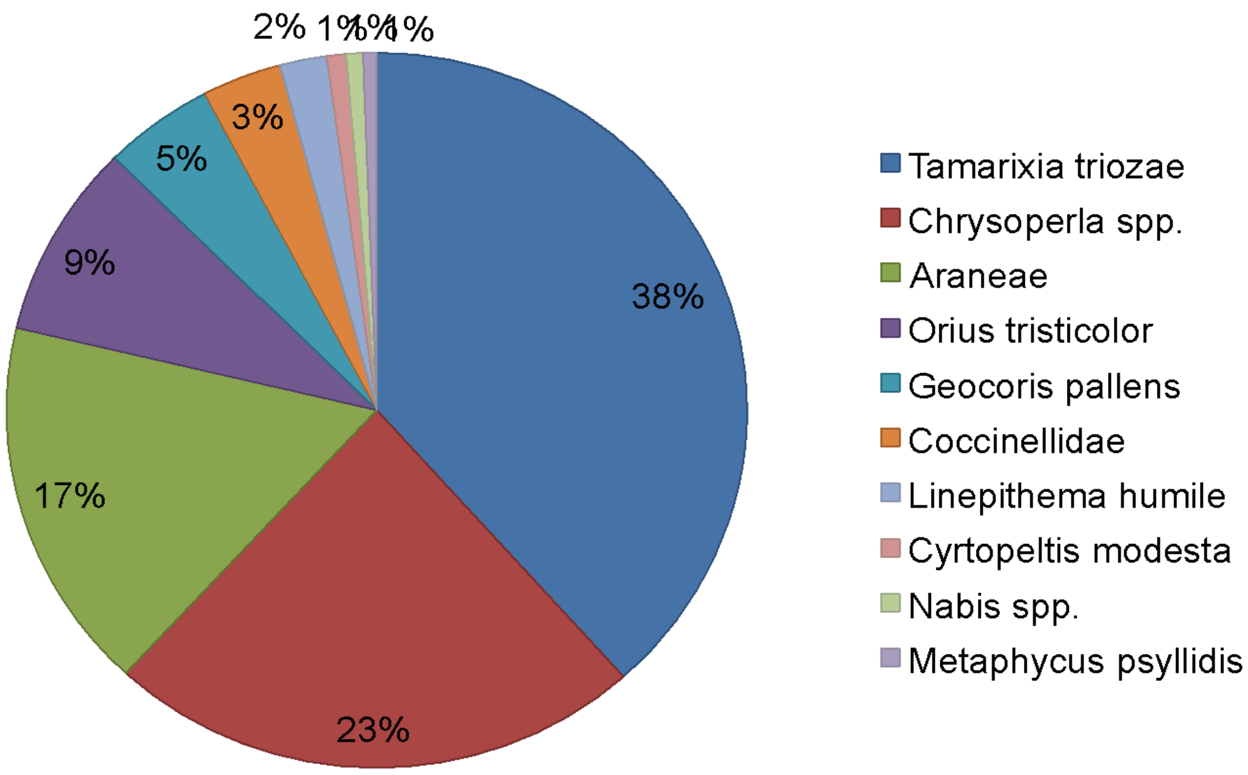
Prager et al., 2017

Because insecticides harm the

FIELD HEROES

THINK BENEFICIALS BEFORE YOU SPRAY

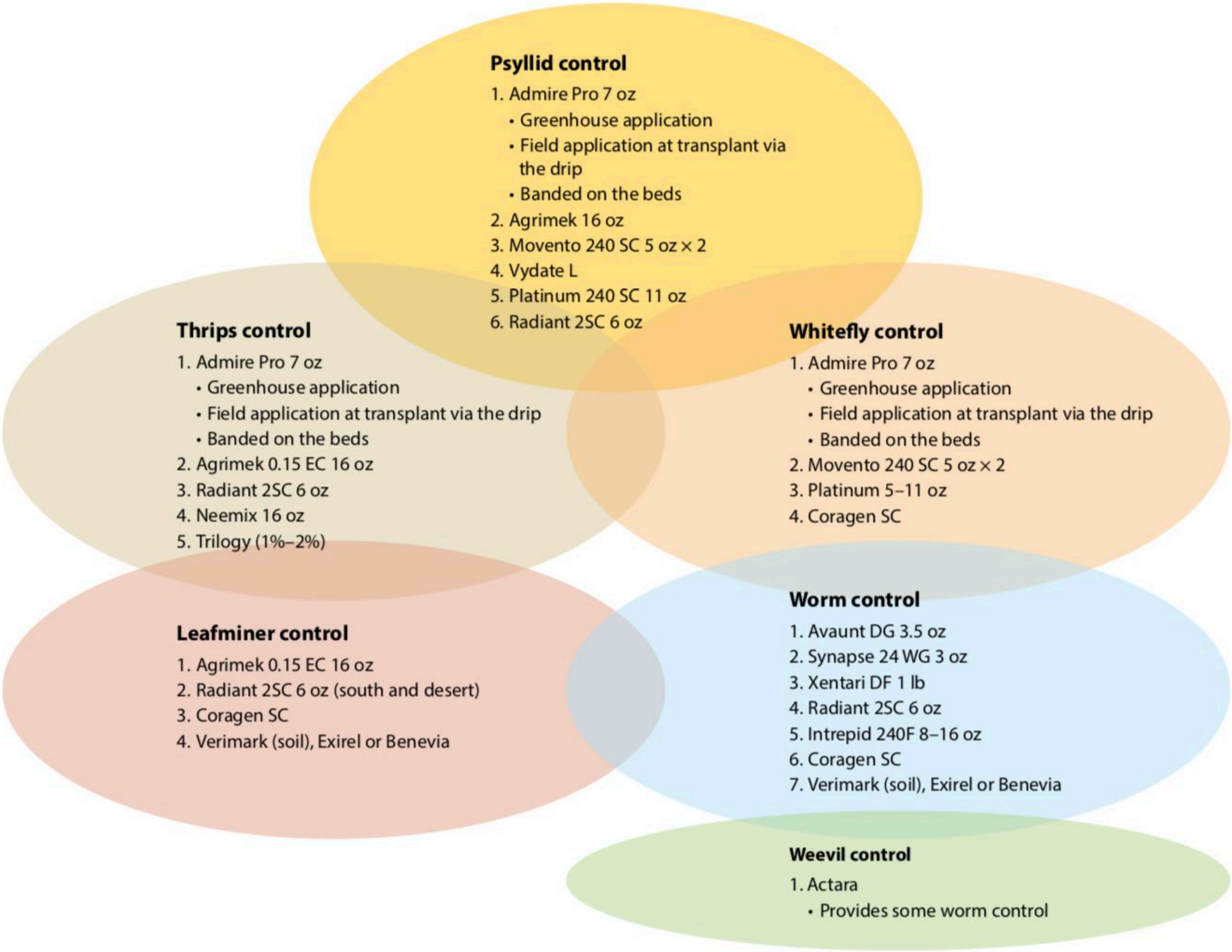
Arthropod natural enemies in bell pepper Orange and Ventura Co. (2009-2010)



But, you can smartly manage the complex

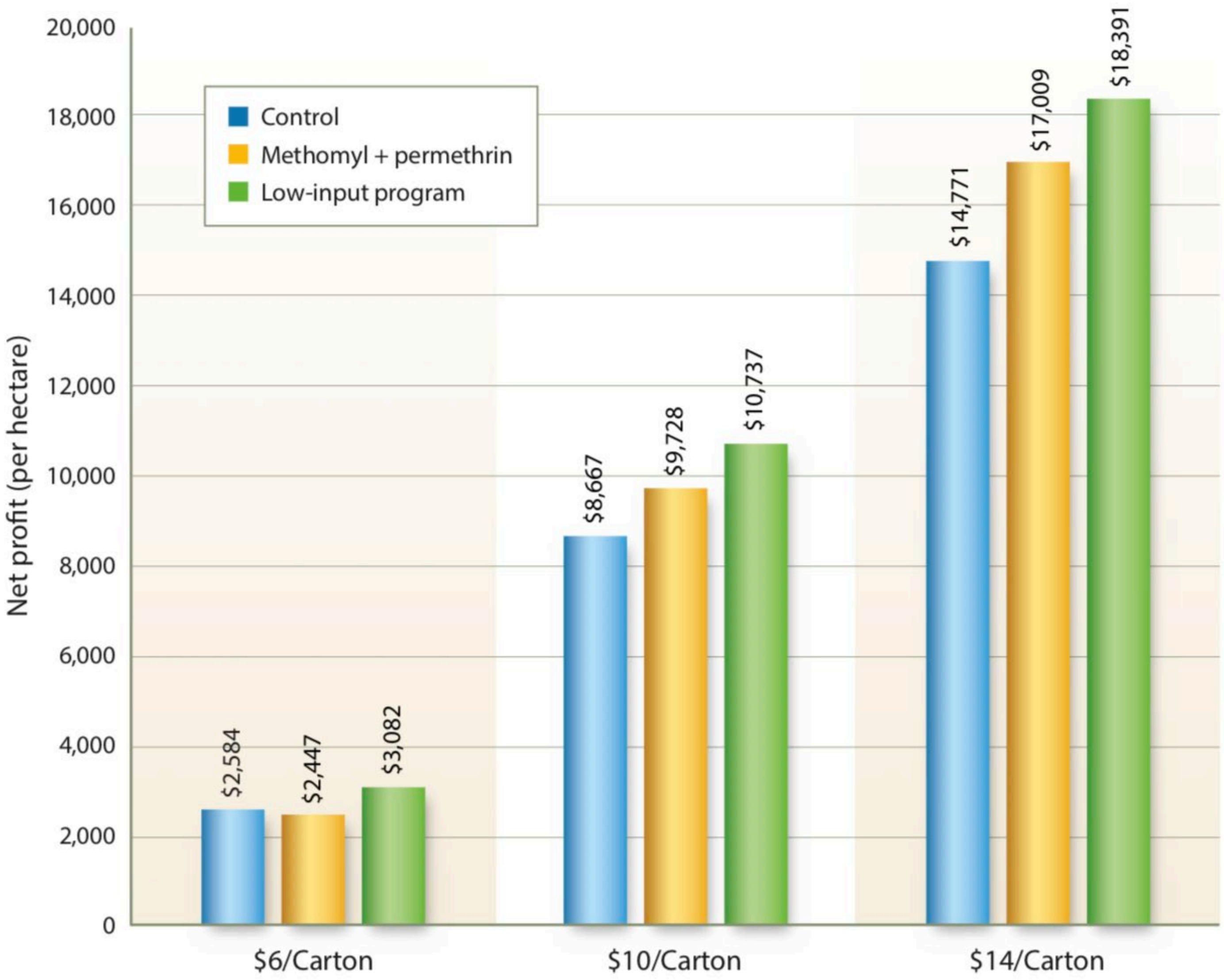
This tool is designed to guide decisions on what material to use.

By choosing overlaps, you can identify insecticides that control multiple pests in a single application.



Prager et al., 2016

And this approach is cost effective



A final thing about the potato psyllids

- In the summer of 2018, psyllids (*Bactericera cockerelli*) and plants infected with the bacterial pathogen *Candidatus* Liberibacter solanacearum (Lso) were detected for the first time in Alberta.
- They are often found in Saskatchewan but no Lso, yet



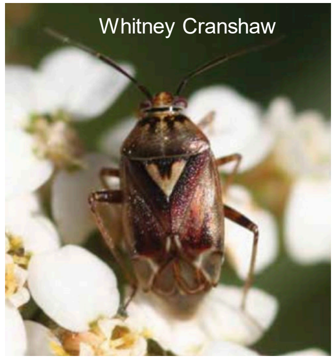
Now, back to the prairies

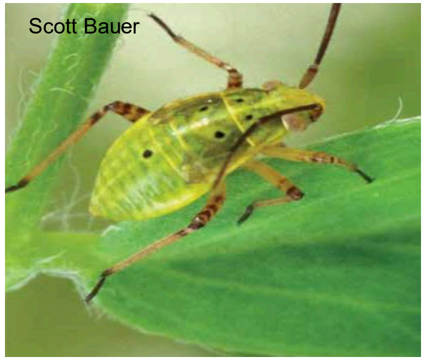
This approach is not horticulture or region specific!

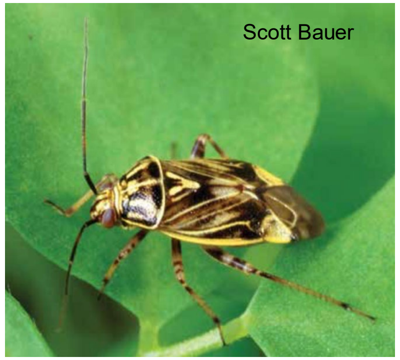
We are applying these approaches to Western Canada

For example, Lygus bugs (*Lygus* spp.)

- *Lygus* is a genus containing multiple species
- Five species in western Canada
- Piercing-sucking mouth parts
- A very minor pests in pulse crops, except fava
- In fava, insects feed on bean pods and damage developing seed
- Causes economic losses because fava beans for human consumption have a very low tolerance for damage (< 1% for Grade #1)

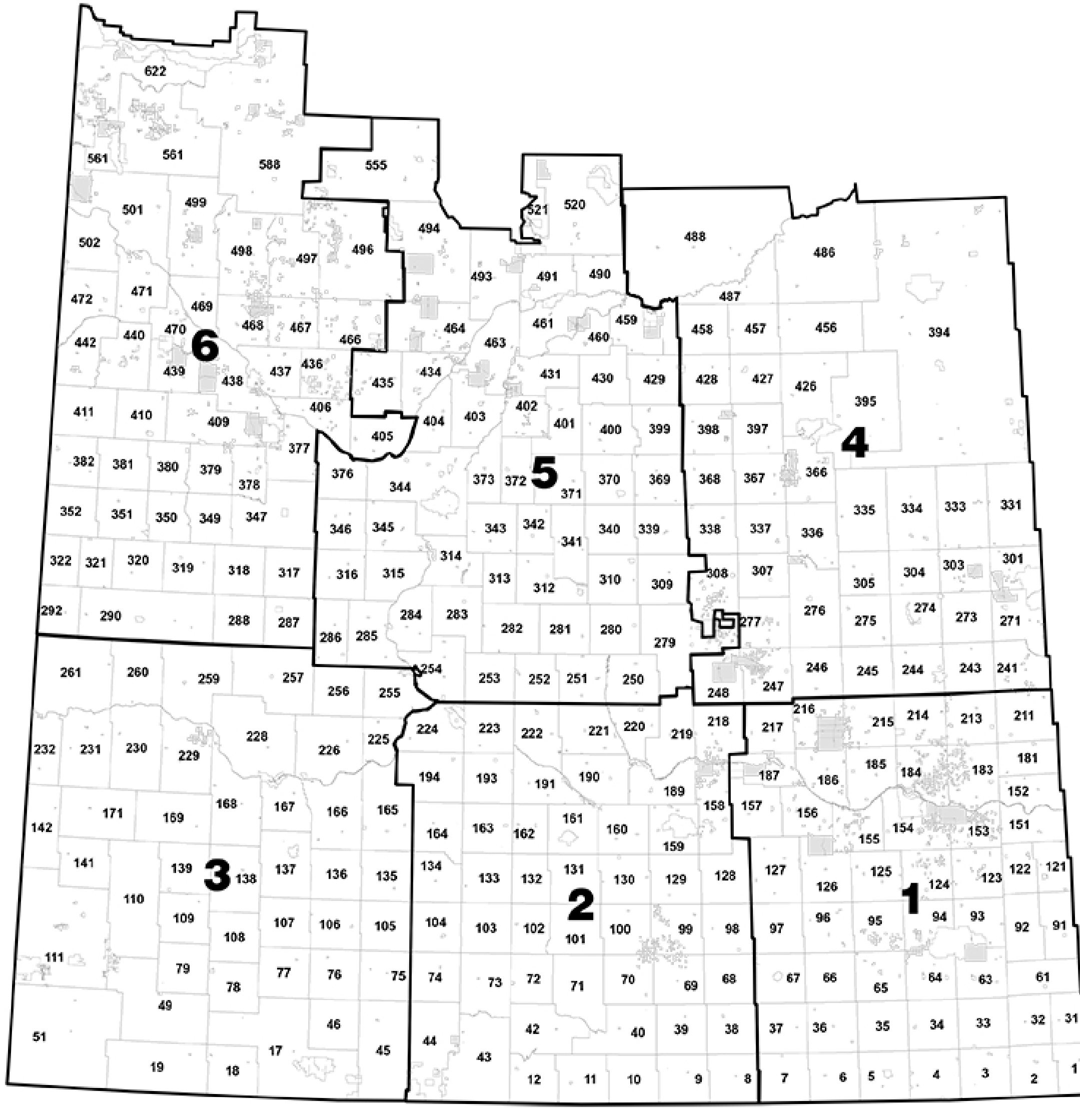






Lygus monitoring

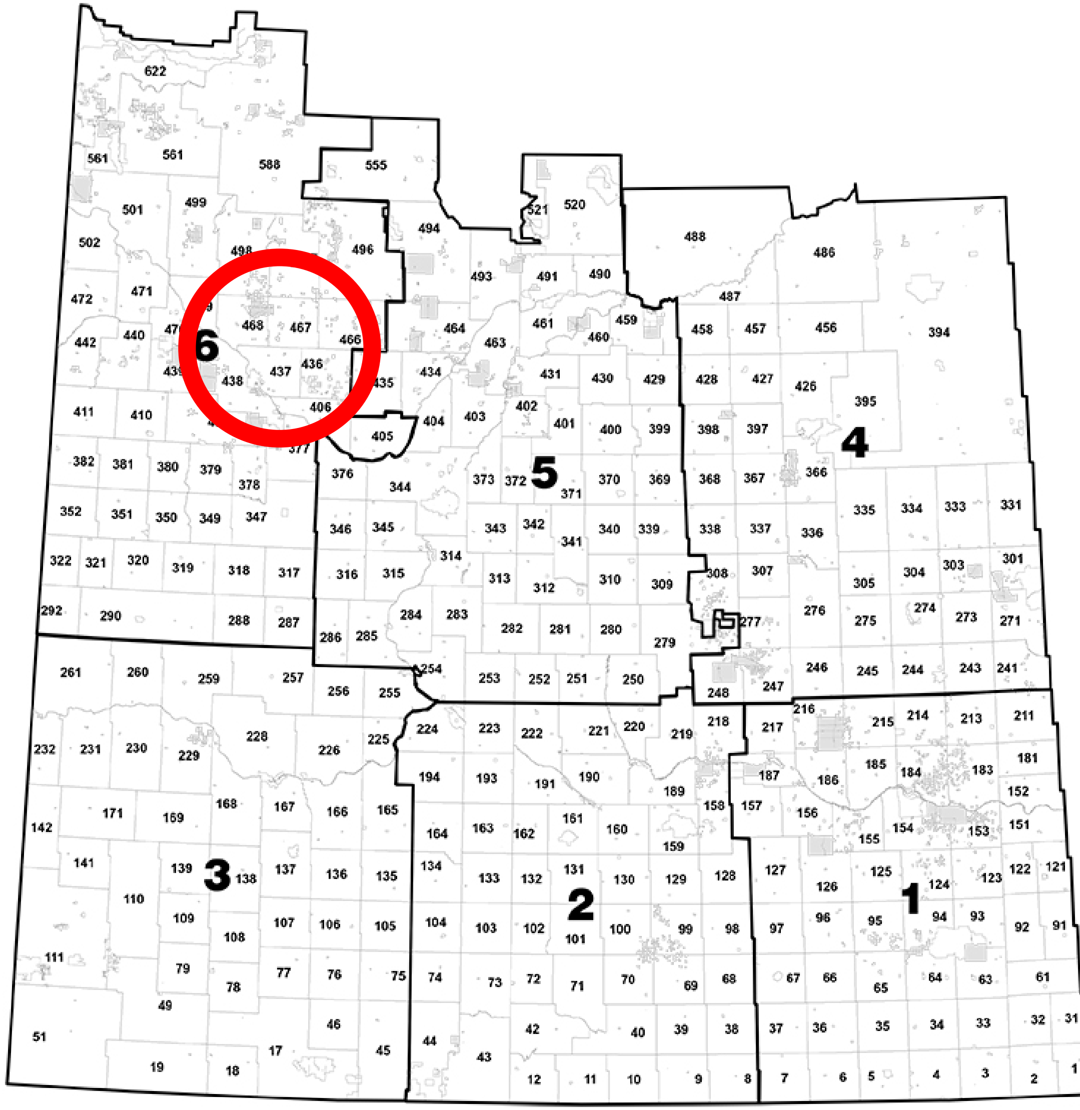
By predicting relative risk from a pest, like Lygus, you can better inform management decisions



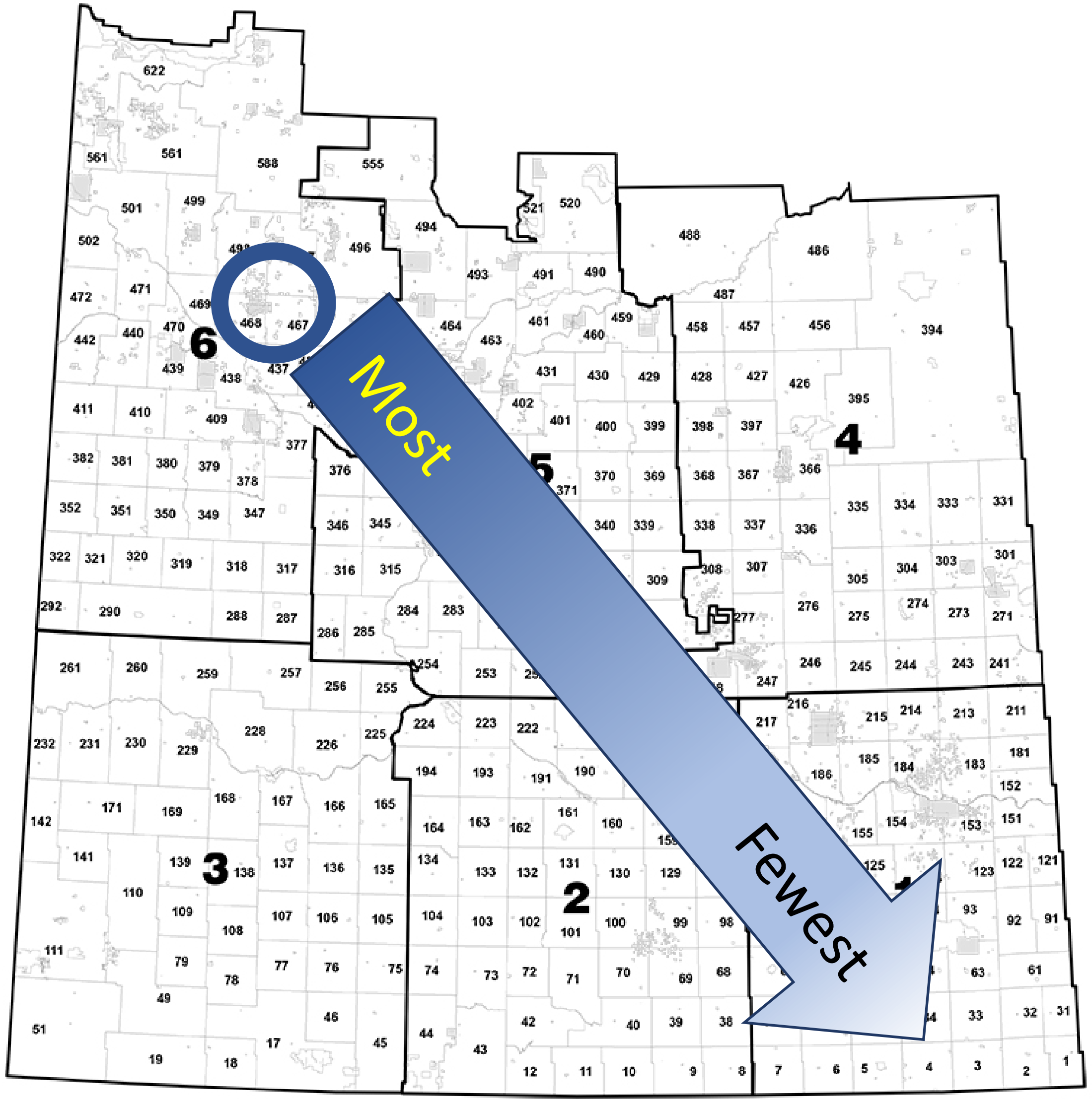
Lygus monitoring

- In 2017, few Lygus in any site
- ¾ of sampled fields had 0 lygus

- No survey in 2018



Lygus monitoring-2019



Another pulse problem-Pea Aphids

Pea aphids (*Acythosiphon pisum*)

- Hemiptera
- Piercing-sucking mouthparts
- Damage plants via feeding on phloem
- Damage plants via virus transmission
- Known to infest all major pulse crops grown in western Canada
- Nearly all recommendations for management in peas
- Few thresholds or sampling protocols for lentils or fava

But, we are working on that

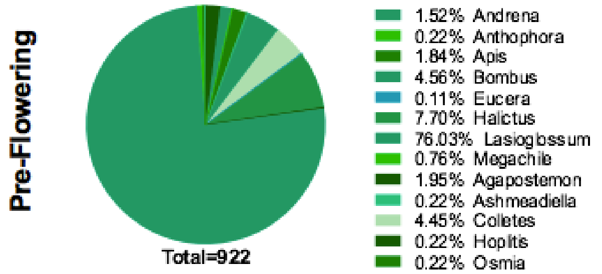
As Ning will detail later, we are:

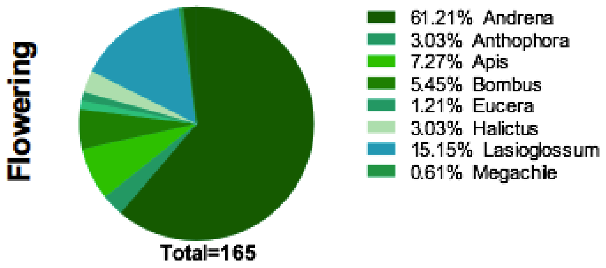
1) Developing economic thresholds for aphids in Lentils and Fava
2) Examining the efficacy of different insecticides

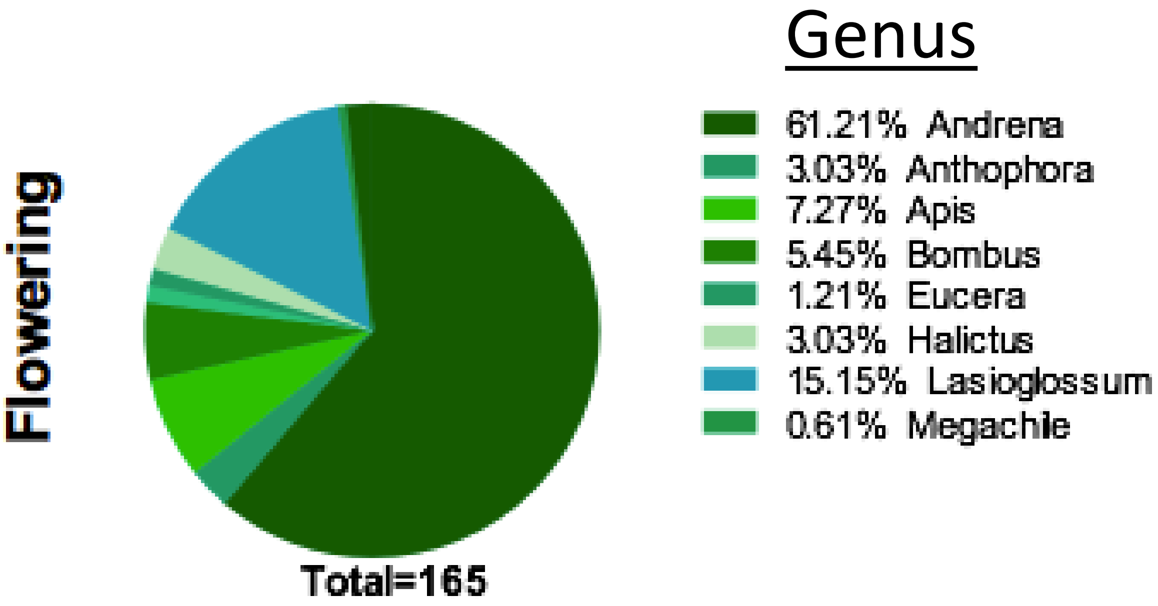
Tyler Wist (AAFC)

Ning Zhou (USASK)

And these decisions should consider pollinators…Because fava fields have bees in them







Bombus

Apis

Andrena

Lasioglossum

We are doing some of this for red clover too

- As Dan will detail, we are examining different insecticides for control of Lesser clover leaf weevil
- This will lead management that is safer for pollinators
- This will lead management that is cheaper
- This will lead management that is more cost effective in general

Dan Malamura

Which brings us to:

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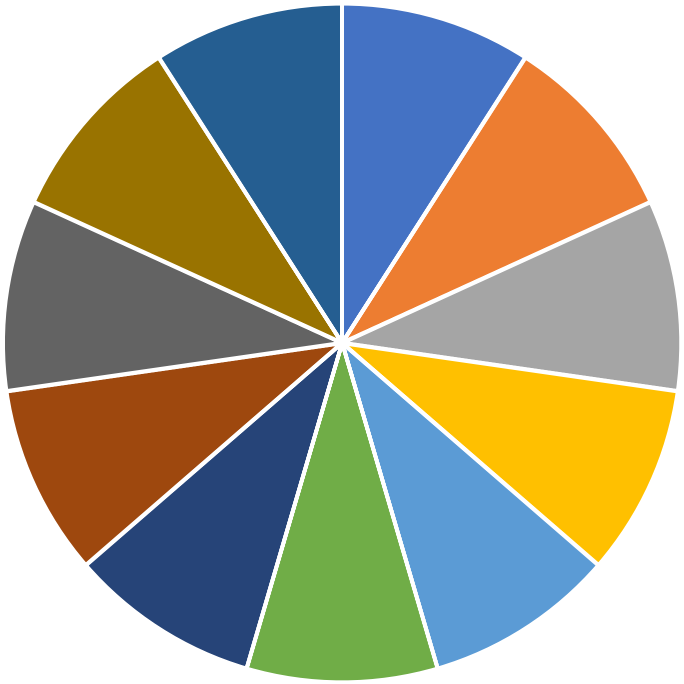
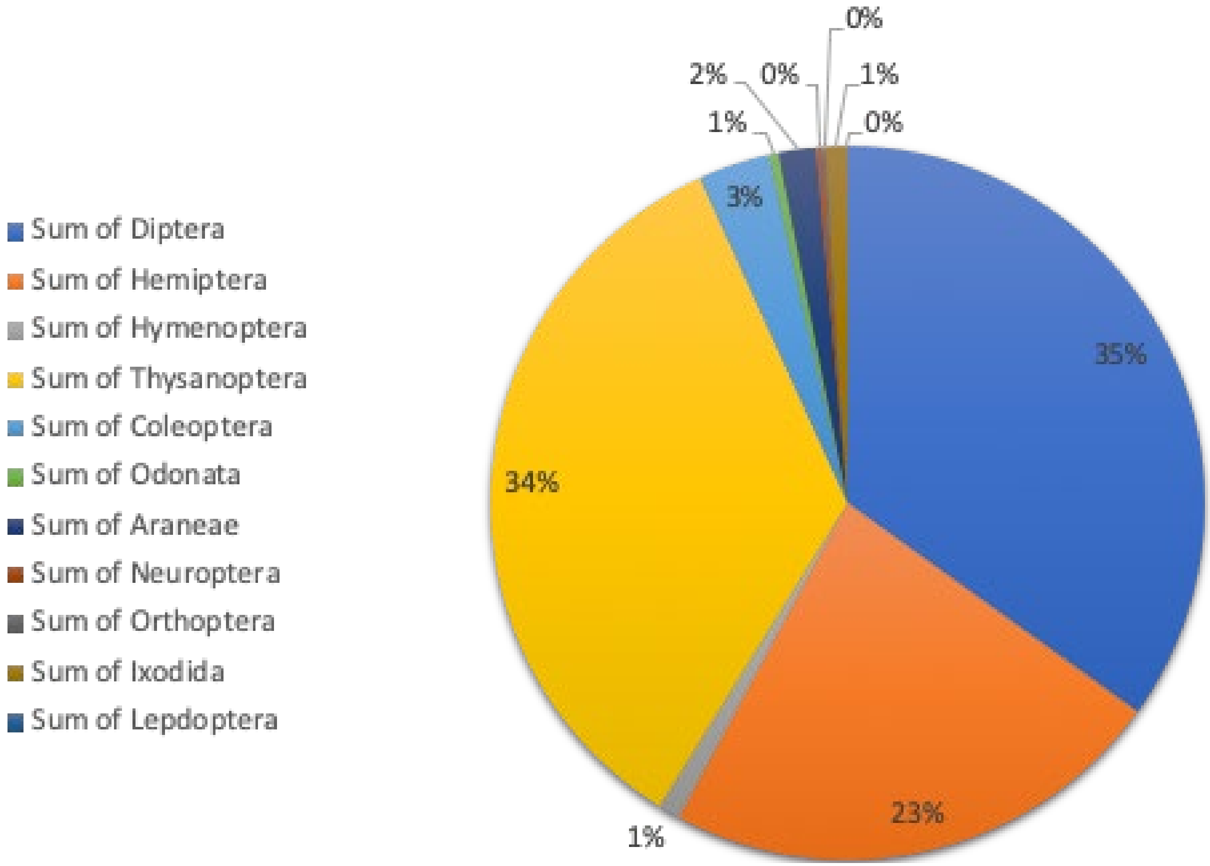
10. Is your crop resistant/tolerant?

We want **even** insect communities

Hypothetical evenness

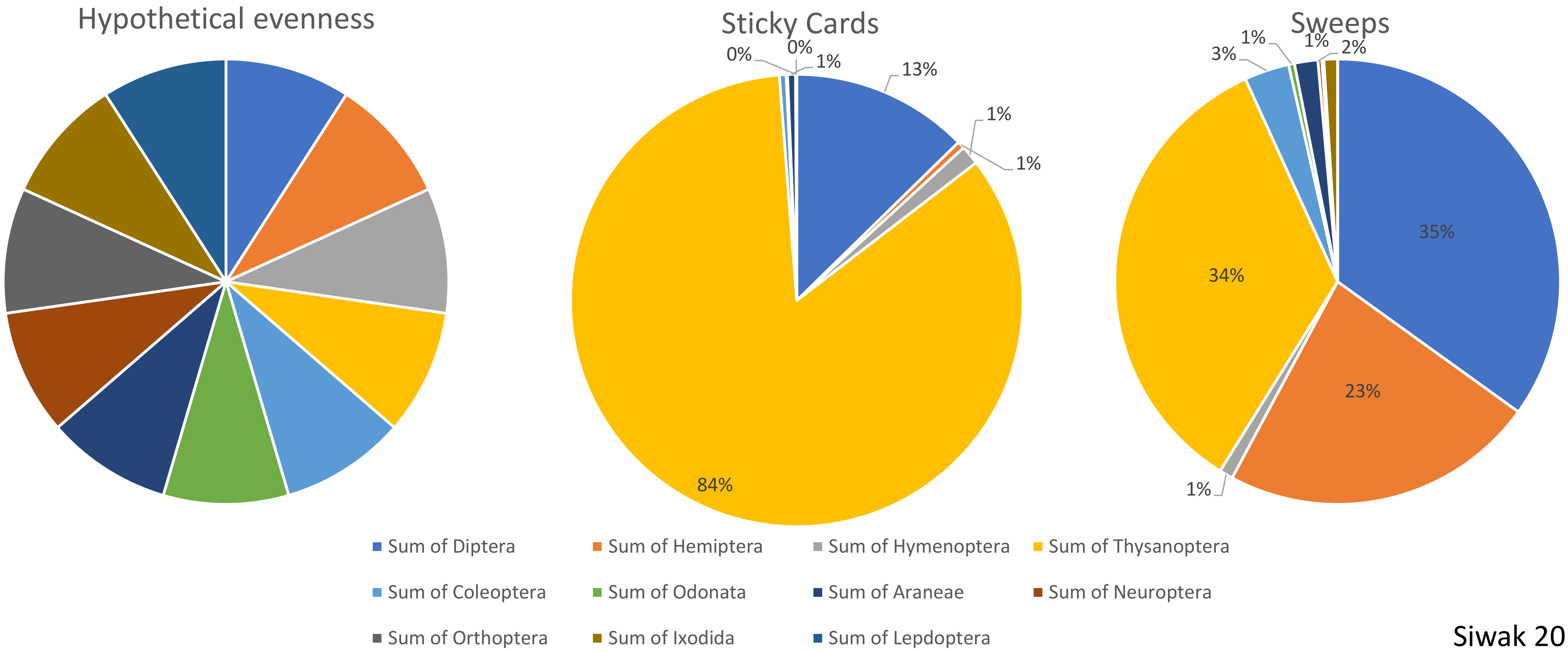


Invertebrate community in Saskatchewan potato fields



Siwak 2017

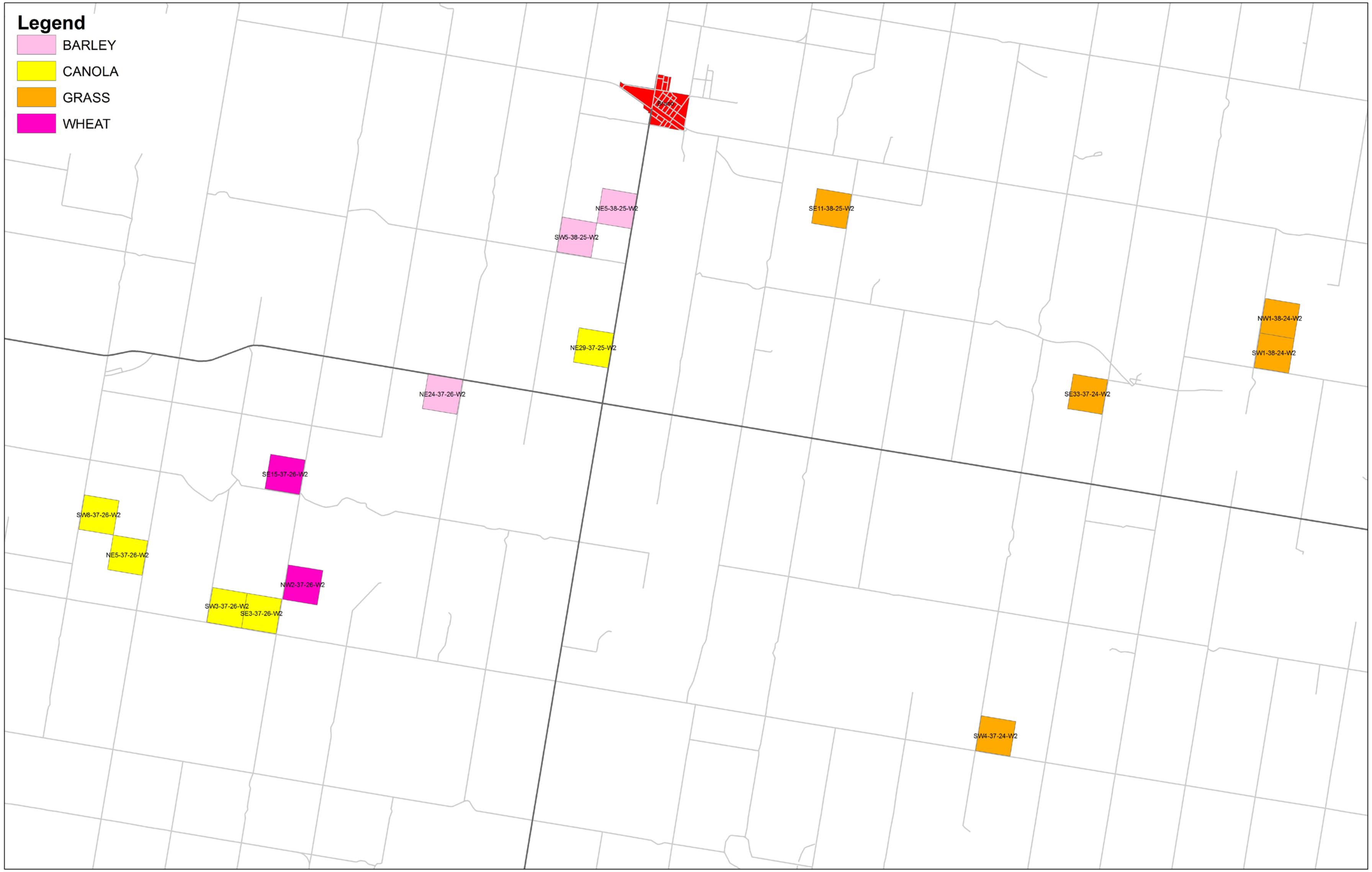
We want **even** insect communities



Siwak 2017

And wetlands can influence insect communities

And we can sample for those insect communities

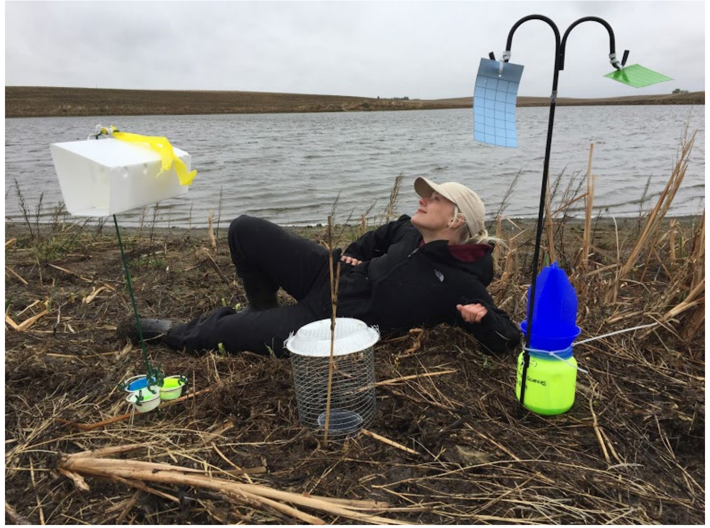


Prairie Pothole Project

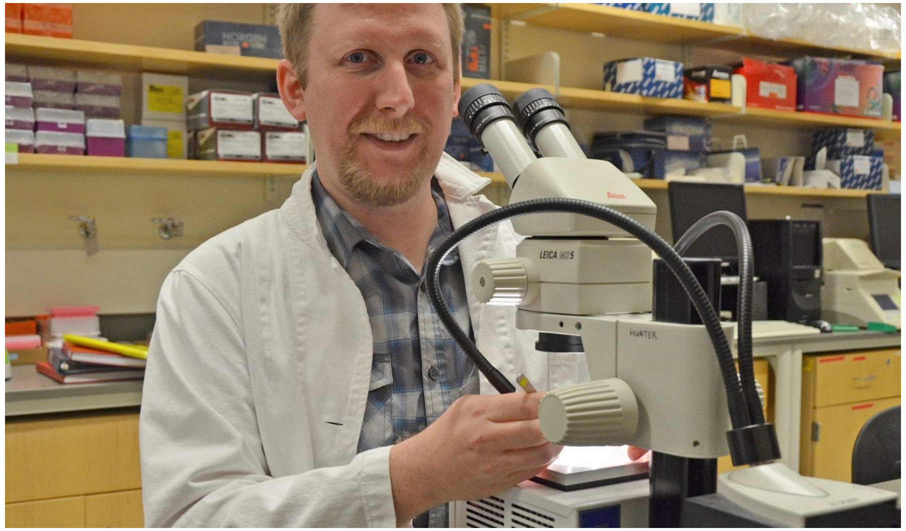
Understanding insect ecology in the prairie pothole region.

- Effect of prairie potholes on insect community composition in farmland and grasslands.
- Sample methods: pitfalls, pans, sweeps, sticky cards, vane trap bycatch.
- Various distances from potholes along transects (25, 75, 150 m).

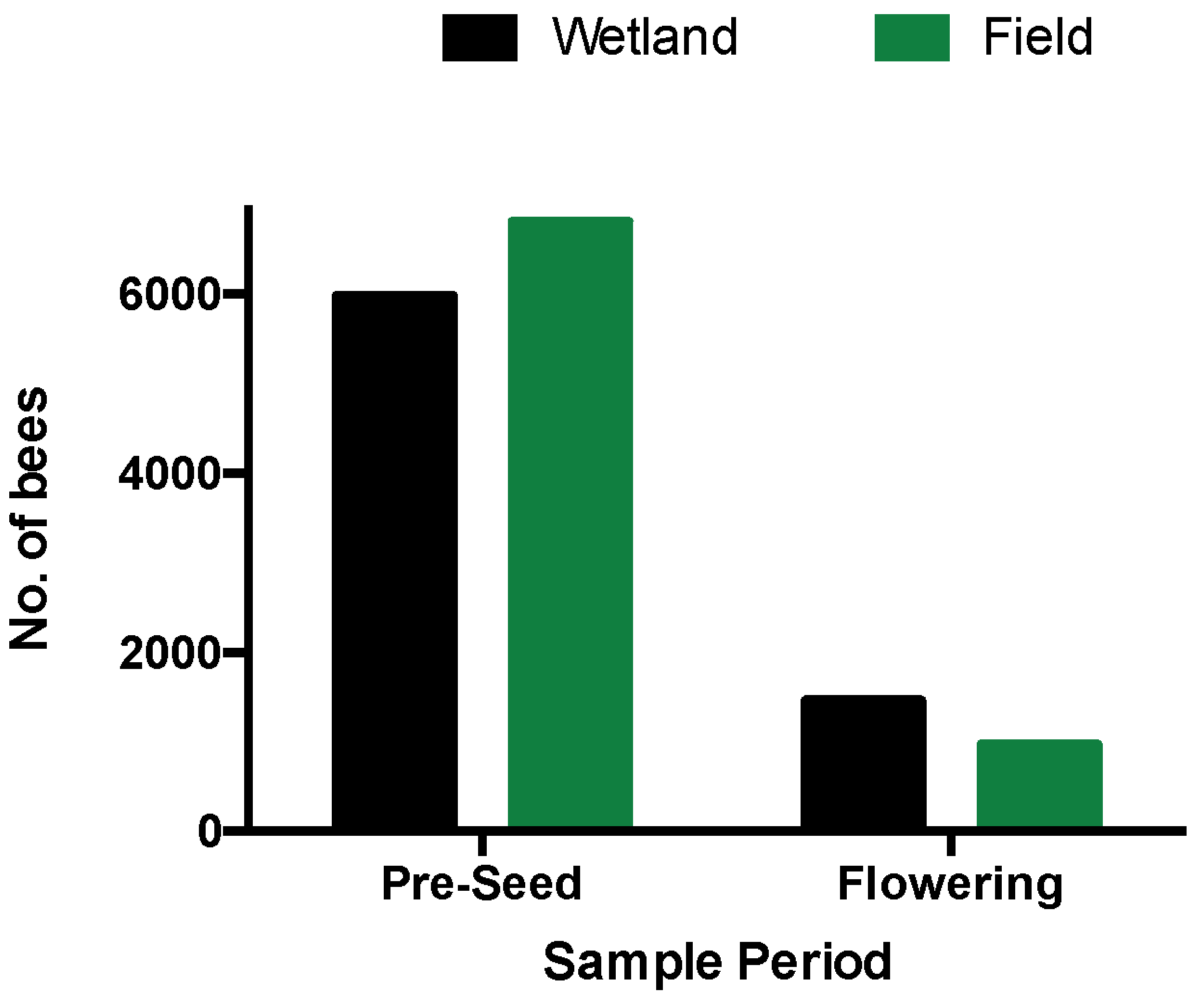
Samantha Morrice



Dr. Adam Jewiss-Gaines

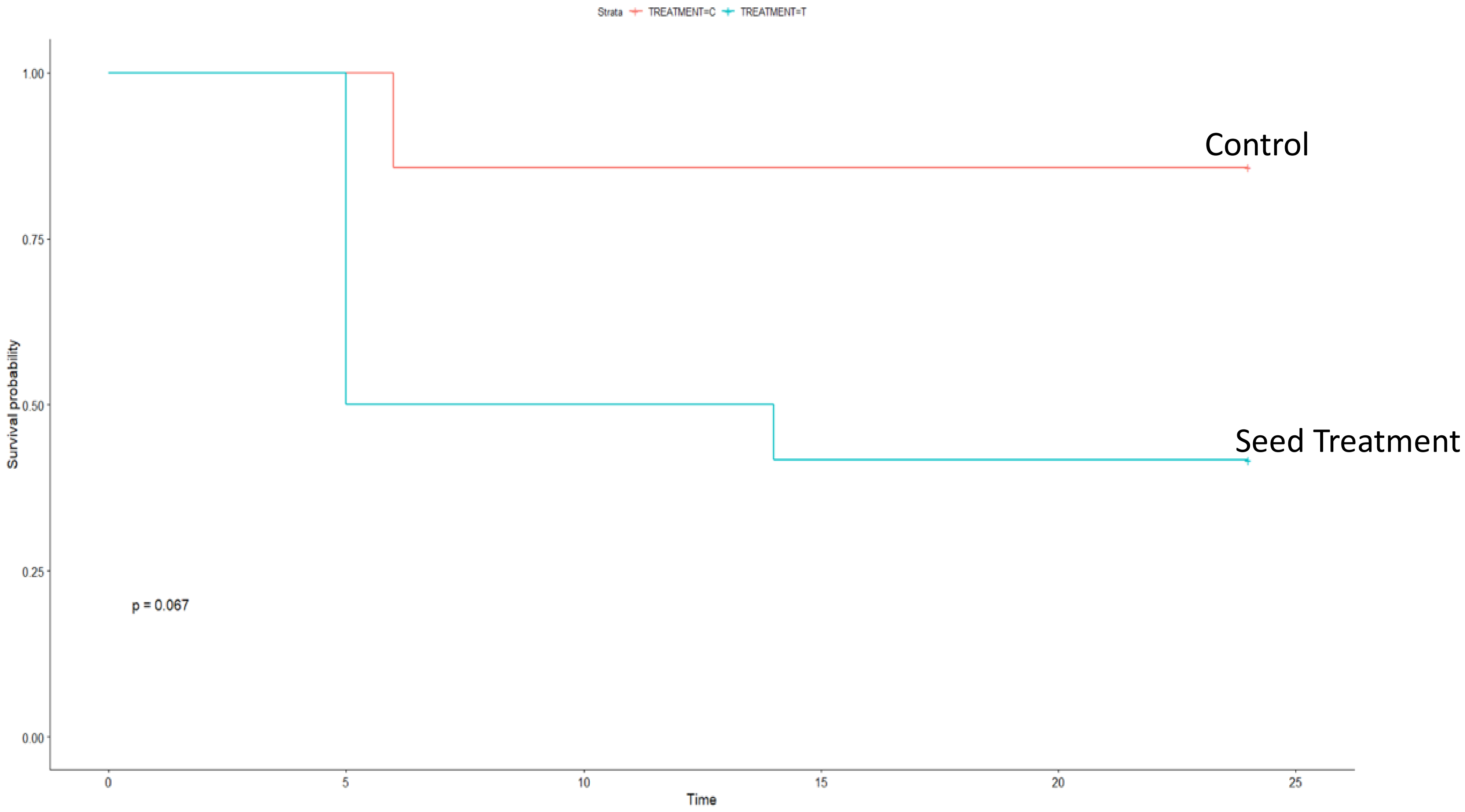


For example: Wetlands may promote pollinators




All this canola is seed treated with an insecticide
Carabid beetles are also in this field
They are eating the canola and hopefully also the weed seeds

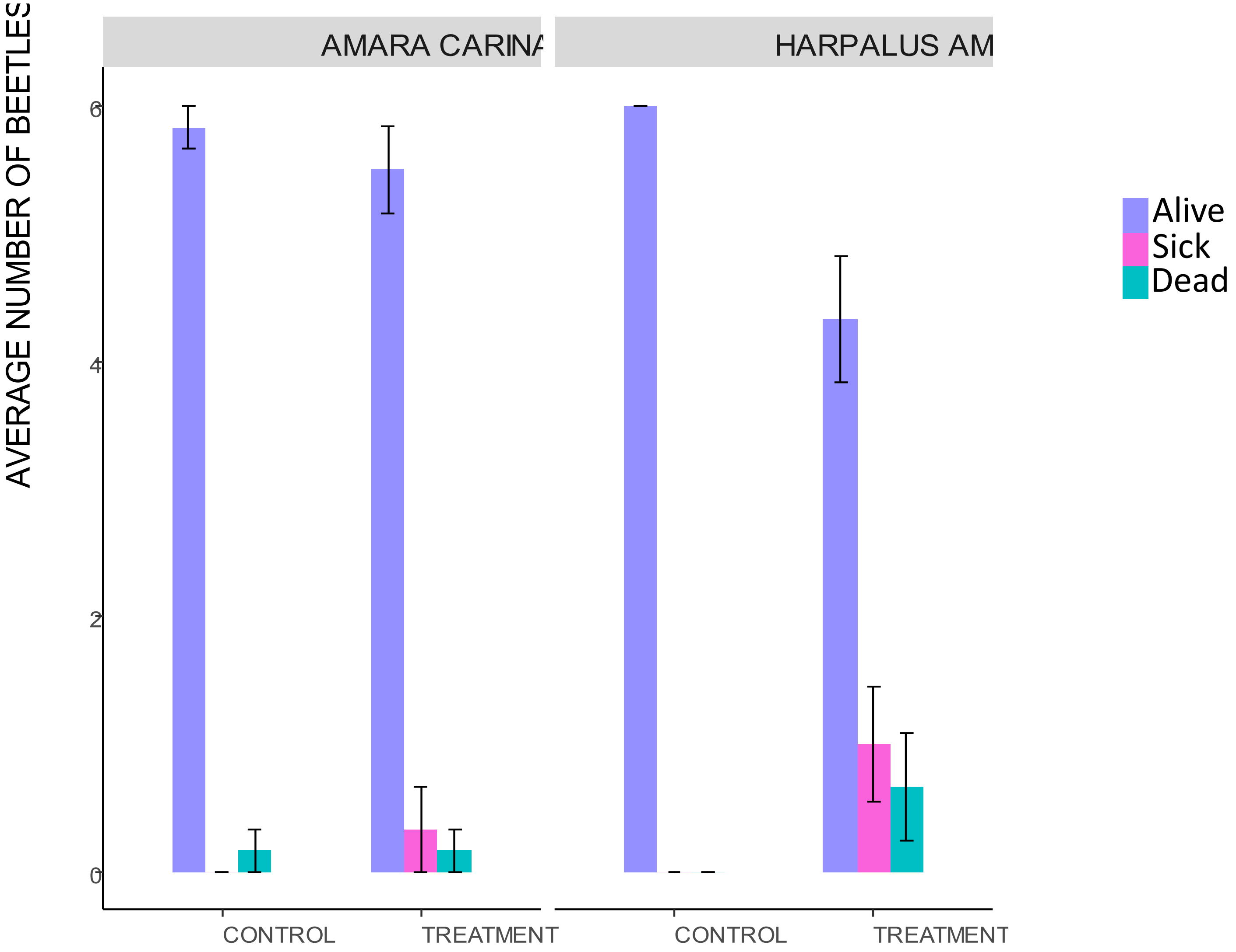
And this may be poisoning the beetles



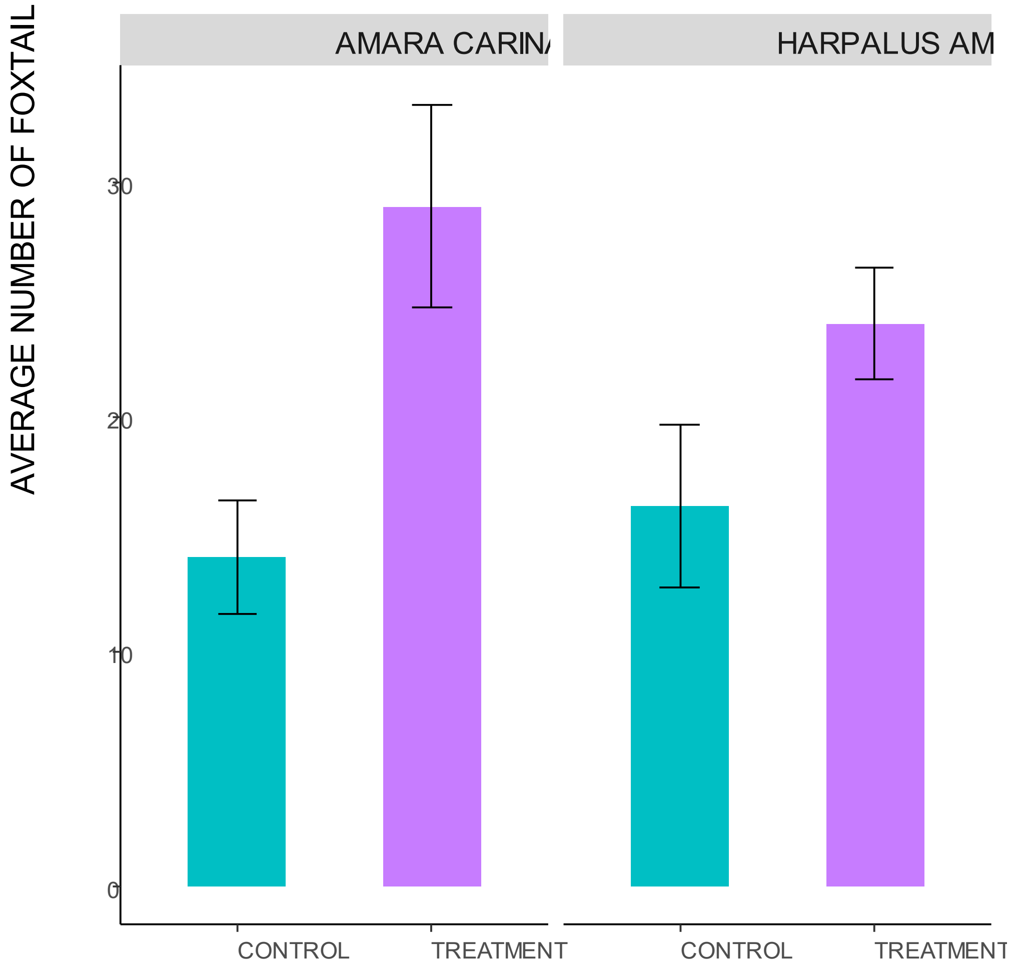
Kirsten Scholten

Stefanie De Heij

And this may be poisoning the beetles



Which might result in less weed control



Let’s look back at the list of considerations:

1. Distribution of pest
2. Which insecticide to use?
3. Is using the insecticide cost effective?
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Screening for aphid resistance

Arguably the best way to manage pests is to develop crops that are not "bothered" by pests

- **Antixenosis:** when a plant possesses traits that result in non-preference, it is referred to as
- **Antibiosis:** when a plant posses traits that influence the development or survival of the insect

Ishita Patel

Pea aphids (*Acythosiphon pisum*)

- Hemiptera
- Piercing-sucking mouthparts
- Damage plants via feeding on phloem
- Damage plants via virus transmission
- Known to infest all major pulse crops grown in western Canada
- Nearly all recommendations for management in peas

Wild lentil vs. Cultivated lentil

- Cultivated lentil (*Lens culinaris*)
  - Commercially grown worldwide
  - Bred for high yield, reduced lodging, and other agronomic traits

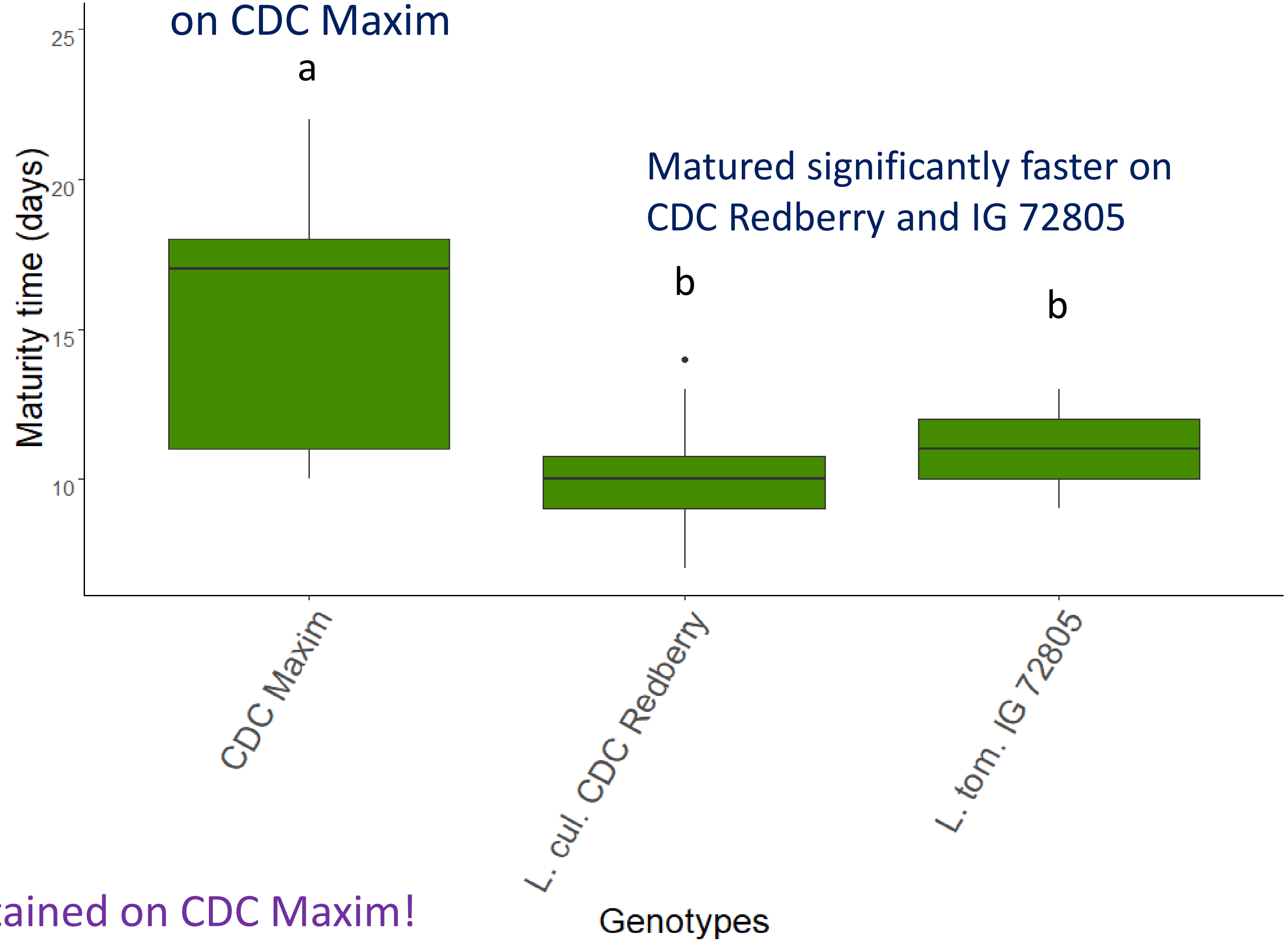
- Wild lentil (*Lens spp.* - 6 species)
  - Low yield, low biomass
  - Thrives in harsh climates by reducing transpiration
  - Has deep root systems
  - Potential source of genetic resources
  - Ex: *Lens tomentosus*

Gorim and Vandenberg (2017) *Front. Plant Sci*. 8:1129

Aphids mature more slowly on cultivated

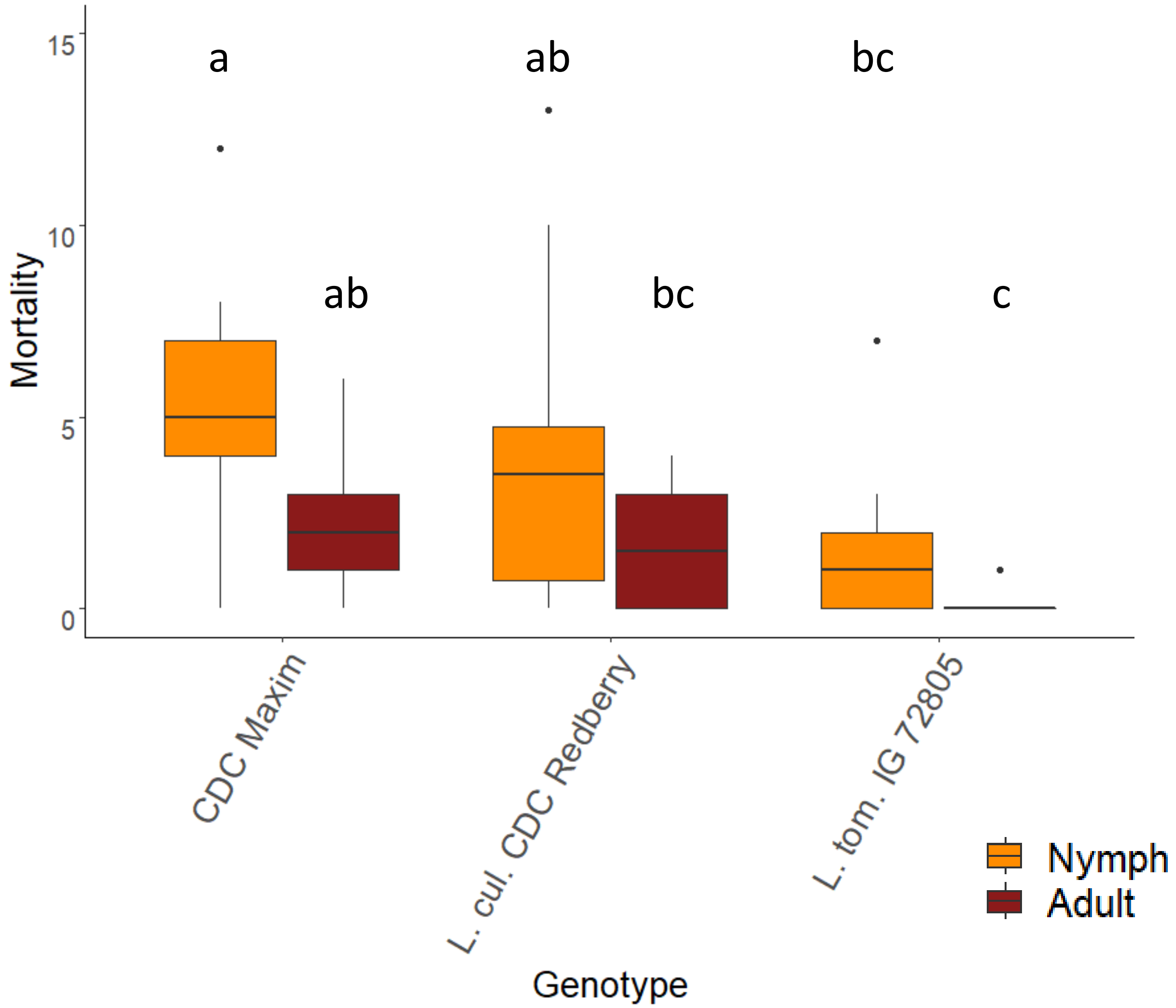
Took most time to mature on CDC Maxim

Matured significantly faster on CDC Redberry and IG 72805



But the colony was maintained on CDC Maxim!

Nymph and adult mortality is higher on Maxim



- CDC Maxim: Highest nymph and adult mortality
- IG 72805: Least nymph and adult mortality, significantly less than CDC Maxim
- CDC Redberry: In between IG 72805 and CDC Maxim, Similar mortality of nymphs and adults to CDC Maxim

Back to the list

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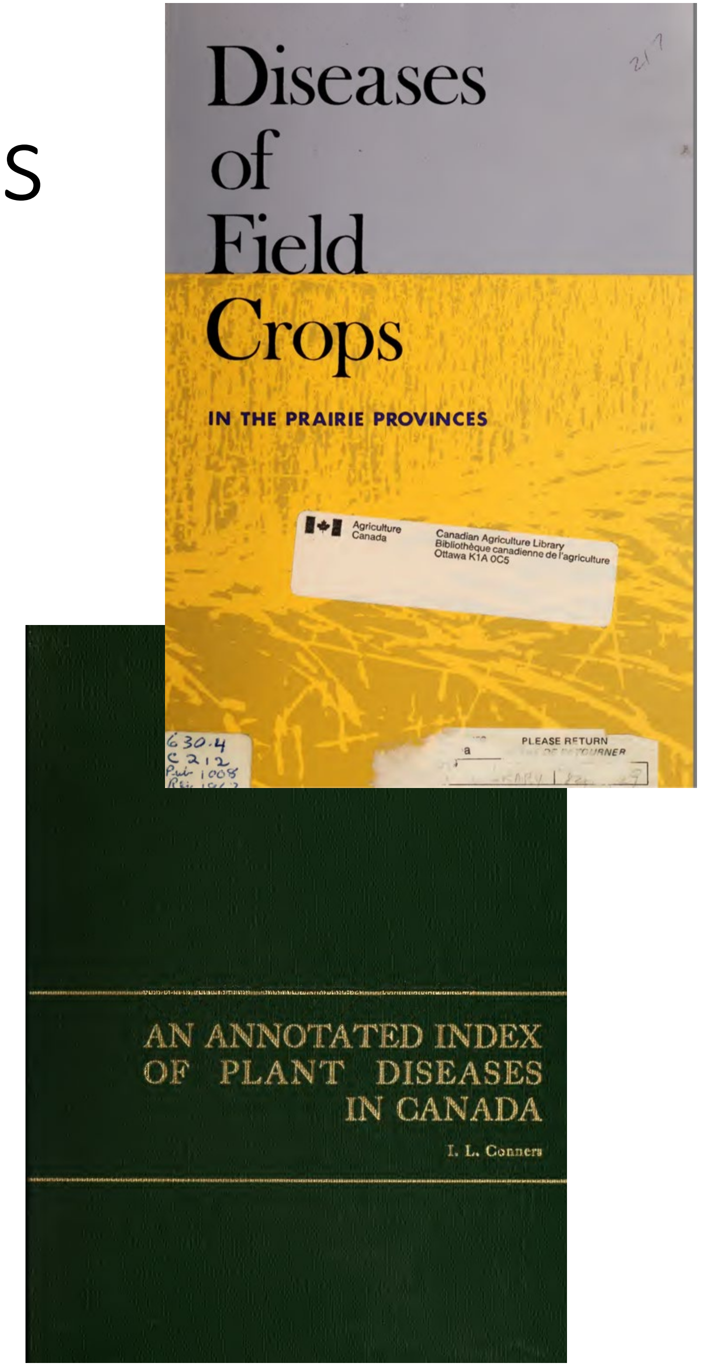
Vectors transmit viruses (and some Mollicutes)

- Historically, few vectored pathogen issues in the Prairies
  - We grow fewer vegetables and horticultural crops
  - Harsher weather has likely kept vector numbers lower
  - Cold winters likely prevented overwintering and thus multi-year outbreaks
- We have also grown a limited set of crops and many have few vectored pathogens
- Detection is often difficult and symptoms can be easily confused
- Many detection methods are molecular and recent

But there were vectored pathogens

Lists the following in (1967 and 1968):

- Agropyron mosaic virus
- Alfalfa mosaic virus
- Barley stripe mosaic virus
- Barley yellow dwarf virus
- Bean mosaic virus
- Clover vein mosaic virus
- Clover yellow mosaic virus
- Mosaic virus in strawberry
- Pea mosaic virus?
- Pea streak virus
- Potato yellow dwarf virus
- Potato virus X
- Potato virus Y
- Raspberry leaf curl virus
- Soybean mosaic virus
- Stripe mosaic virus in wheat
- Sweet clover mosaic virus
- Wheat spot mosaic virus
- Wheat streak mosaic virus in wheat
- “Aster Yellows Virus” (actually phytoplasma)



A total of 19 pathogens

And some are in Manitoba (2018)

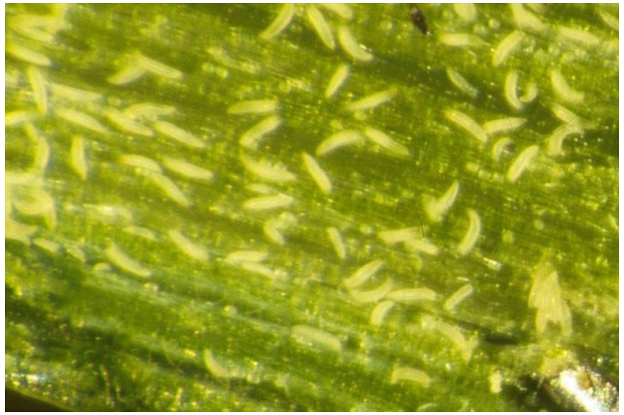
- Wheat streak mosaic virus
- Potato virus X in potato
- Potato virus Y in potato
- Potato virus S in potato

Manitoba (2018)

- In Manitoba
  - Wheat streak mosaic virus

Aceria tosichella

Wheat curl mite



And Alberta (2018)

- In Alberta:
  - Potato virus Y in potato

Myzus persicae

Macrosiphum euphorbiae

And especially Saskatchewan

- Over the past few years we have detected multiple Potyvirus positive pulse plants in Saskatchewan
  - Found in faba and field pea
- These have all tested positive for *Pea Seedborne Mosaic Virus* (PSbMV)
- Some of these correlate to high aphid numbers in the last few years

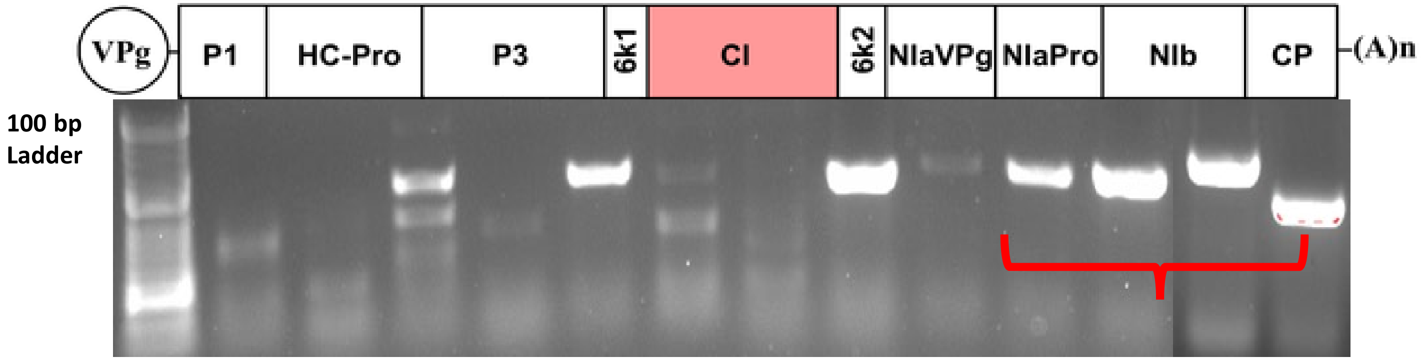



Pea seedborne mosaic virus (PSbMV)

- Genus: *Potyvirus*, Family: *Potyviridae*)
- Positive-sense genomic RNA. Genome size approximately 9.8KB.
- The natural hosts are within the Fabaceae
- Important pathogen on pea, chickpea, lentil and broad (Faba) bean.
- PSbMV is seed, mechanically and aphid transmissible by multiple aphid species including the pea specialist *A. pisum*
- Four pathotypes of PSbMV(P1- P4) - based on their ability to overcome the recessive *sbm* genes present in differential host pea lines
- Pathotypes can be inferred through genetic information (CP and HC-Pro gene phylogeny).

(further reading Rashed *et al.*, 2018 doi.org/10.1093/aesa/say014)

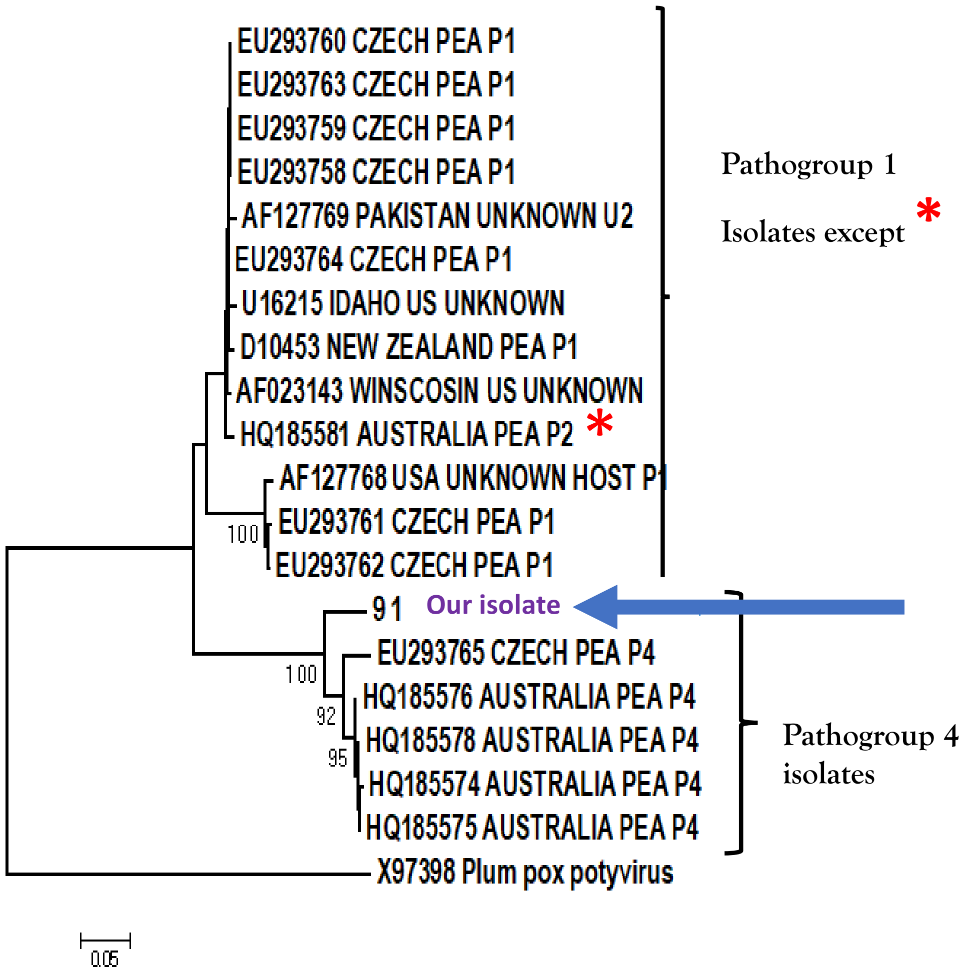
Nucleotide sequence BLAST confirms identity and phylogeny suggests association with pathogroup 4 isolates



2686bp section corresponding to position 7219-9908 of PSbMV genome

BLAST shows 94.12 Sequence similarity to isolate from New York (GenBank ID: X89997) and 84-85% similar to European isolates

Next steps: Whole genome sequencing by Illumina for multiple isolates

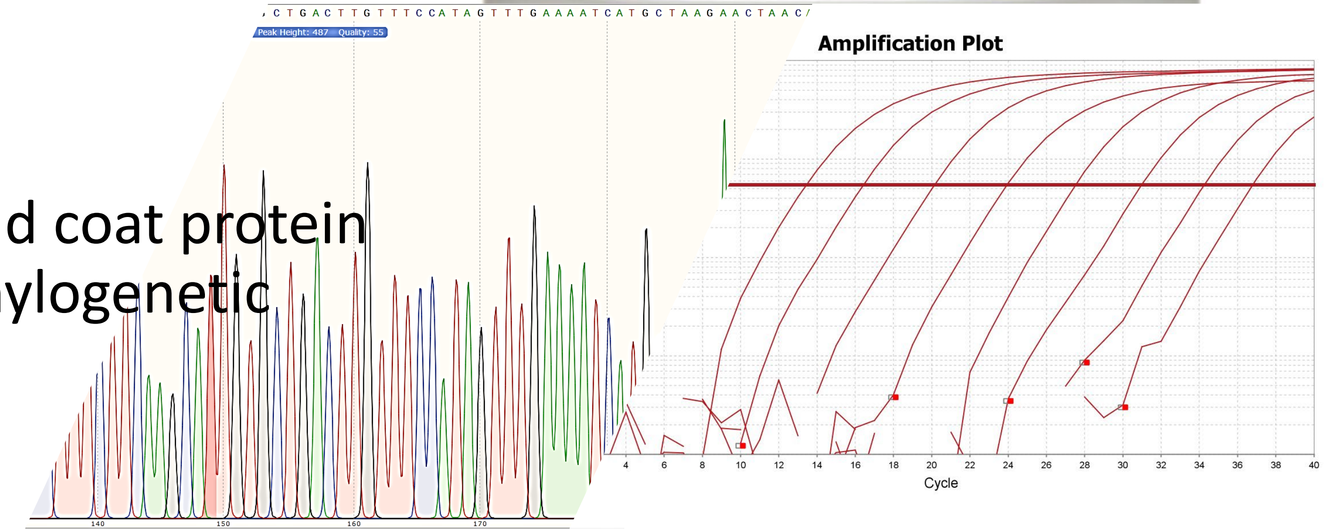


Neighbor-Joining method used to generate tree. Analysis involved 20 nucleotide sequences conducted in MEGA7

Dr. Francis Wamonje

So, we have developed detection tools

- RNA extracted and cDNA generated using random hexamers for RT PCR and qPCR.
- FAM-labelled TaqMan assay designed based on the coat protein for PSbMV (MK116871) to amplify a 300bp fragment of the *CP* gene (positions 287 to 587).
- Primers for PSbMV genome sequencing designed from full length sequence of PSbMV (NC_001671.1). Designed to amplify approximately 600-900 base pair (bp) sections with a 50-100bp overlap.
- Amplicons were purified and sequenced
- Regions corresponding with the NIa NIb and coat protein were sequenced and used in BLAST and phylogenetic analyses



But more are likely coming

- There are at least 33 vectored viruses of pulses in North America
- Seven families
- Many are vectored by insect species that are rare in the prairies and northern United States

Whiteflies (*Bemisia spp.*)

Various leafhoppers

Rashed et al., 2018

Let’s look back at the list of considerations:

1. Distribution of pest
2. Which insecticide to use?
3. Is using the insecticide cost effective?
4. Is this a common pest or an unusual/uncommon one?
5. Beneficial insects and/or pollinators
6. Neighbors
7. Other susceptible crops
8. Perhaps weeds?
9. Is the pest a vector?
10. Is your crop resistant/tolerant?

Aster Yellows Phytoplasma

- Historically one of the most reported vectored pathogens
- Associated with dozens of crops including: cereals, canola, pulses
- Transmitted by the Aster Leafhopper

Macrosteles qudrarilineatus
Aster leafhopper

Host choice in Aster Leaf Hoppers

Leafhoppers and Aster Yellows are a complicated problem.
Their outbreaks can be influenced by many factors:

- Neighboring crops
- Weeds
- Weather
- Vector dynamics

But we are working on this too

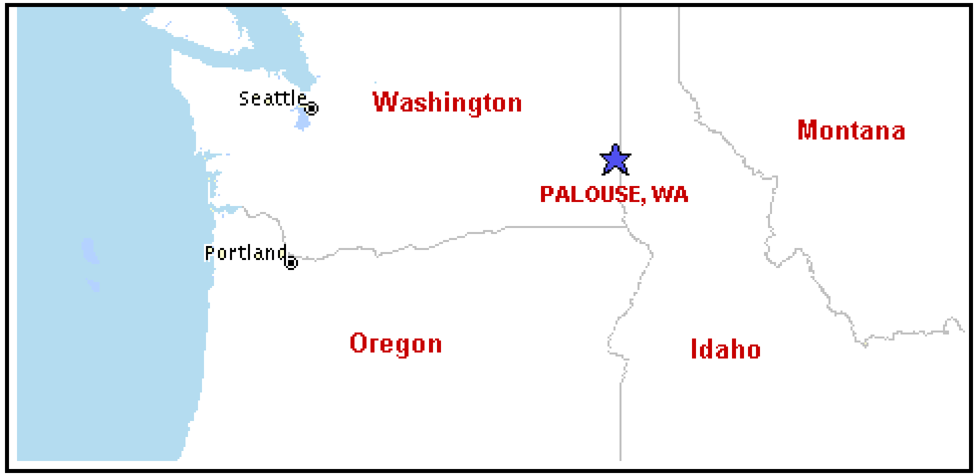
Tyler Wist (AAFC)

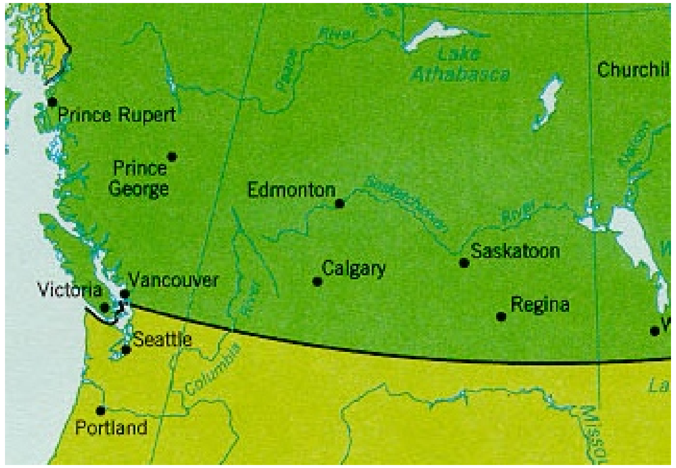
Berenice Romero

Chrystel Olivier(AAFC)

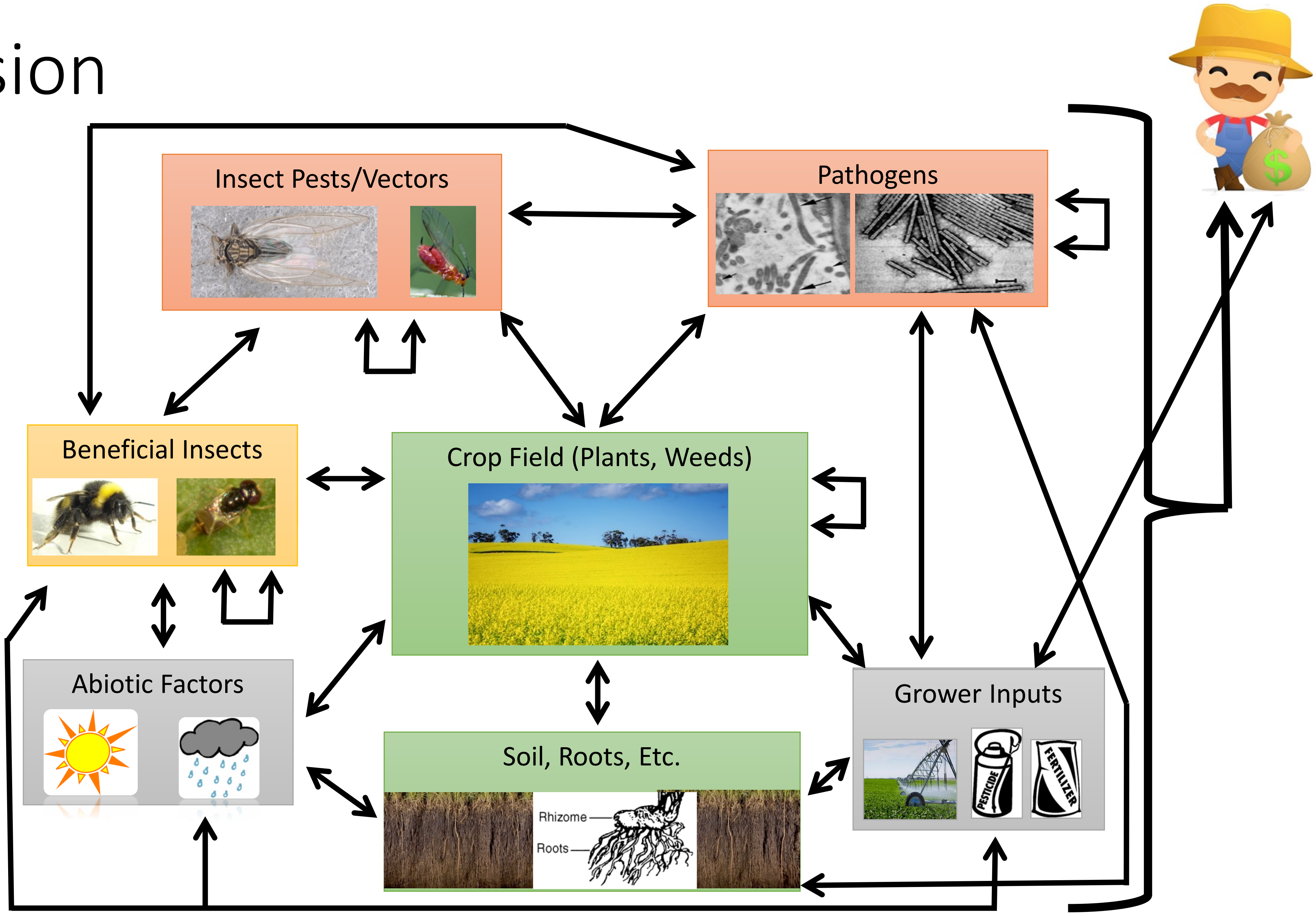
Finally, the Future = More Problems

- Currently, outbreaks from vectored pathogens are rare
- However, as climate changes and we change are agricultural practices this is likely to change
  - **ESPECIALLY IN THE PULSES!**
  - Remember many of pathogens are just missing the vector
- We already are seeing more issues in the Northern USA





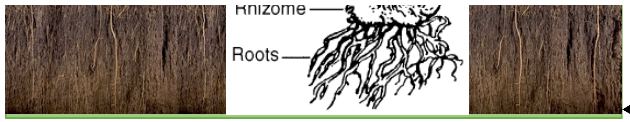
In Conclusion

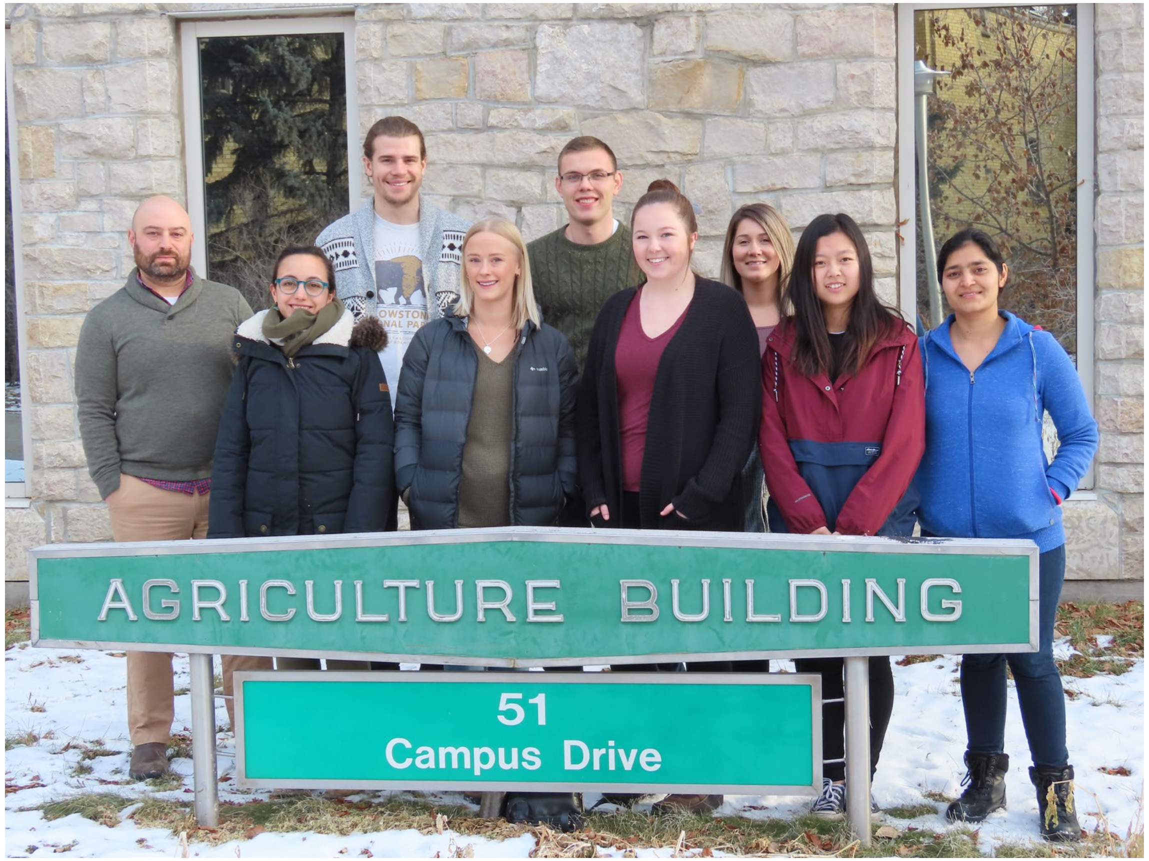


In Conclusion

This is a complicated mess. But, we considering the mess can lead to better management decisions and reduced biotic stress.

And this can lead to better yields and profits





Prager lab
Berenice Romero
Ning Zhao
Dan Malamura
Caleb Bryan
Samantha Morrice
Ramandeep Bamrah
Francis Wamonje
Adam Jewiss-Gaines
Kirsten Scholten

UC Riverside
John T. Trumble
Greg Kund
William Carson
Beatriz Vindiola
Nichole Drew
Haylee Drew
Kris Gilbert
Sam Gilbert
Michael Jones

AAFC
Tyler Wist
Chrystel Olivier

USASK
Chris Willenborg
Bert Vanderberg
Sabine Banniza
Stefanie De Heij

Saskatchewan Pulse Growers
Government of Saskatchewan
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California Potato Research Advisory Board
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SaskCanola
Environment Canada
Ducks Unlimited Canada

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